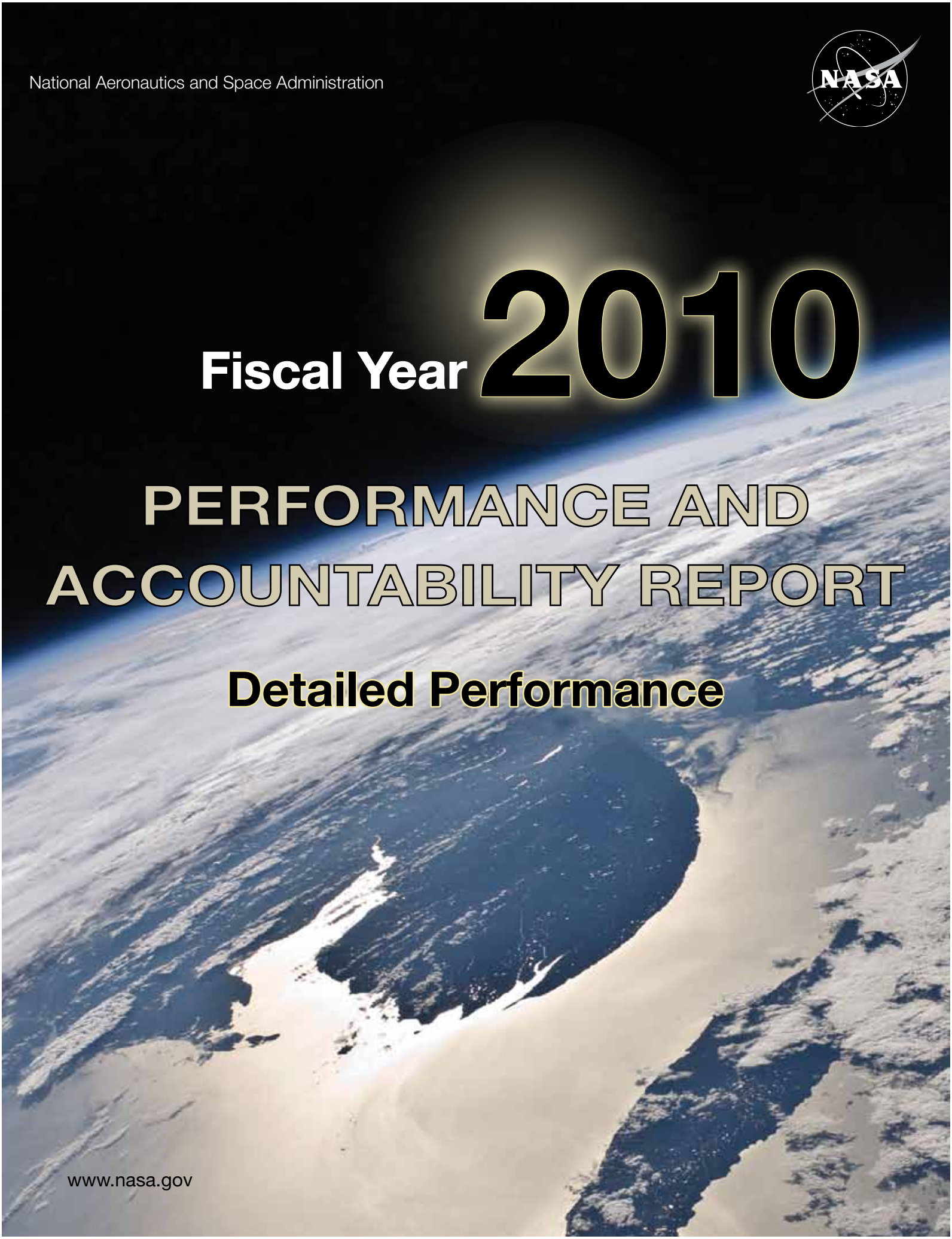
National Aeronautics and Space Administration



# Fiscal Year 2010

# PERFORMANCE AND ACCOUNTABILITY REPORT

## Detailed Performance

www.nasa.gov

# Message from the Administrator

November 15, 2010

I am pleased to present NASA's FY 2010 Performance and Accountability Report (PAR). This report documents NASA's progress toward achieving the challenging mission of space exploration, scientific discovery, and aeronautics research as outlined in our Strategic Plan. Further, the performance and financial information presented in this report highlights our efforts to manage taxpayer dollars responsibly, while adhering to NASA's core values of Safety, Integrity, Teamwork, and Excellence.

We are proud of all of our accomplishments this year, and specific information is highlighted and discussed in the *Detailed Performance* Section of this report. However, I would like to mention a few of our specific accomplishments. We had four successful Space Shuttle launches to the International Space Station (ISS) since last November, to complete its construction and outfit it as a scientific facility like no other. The 10th anniversary of humans aboard the station was a true milestone, and we're entering an era where it will reach its true potential as an orbiting laboratory. Likewise, we were pleased to recognize the 20th anniversary of the launching of the Hubble Space Telescope and to begin seeing new results from the instruments with which it was outfitted on last year's servicing mission. This year, we also marked the 50th anniversary of weather observations from space—a year in which our Earth-observing satellites were also helpful in assessing the status on the ground after disasters such as the Haiti earthquake and the Gulf oil spill. Most recently, a NASA team assisted the Chilean government, through the U. S. Department of State, to provide technical advice that assisted the trapped miners at the San Jose gold and copper mine.

NASA launched the following science missions: Widefield Infrared Survey Explorer (WISE); Solar Dynamics Observatory (SDO); and Geostationary Operational Environmental Satellite (GOES). WISE will scan the entire sky to uncover objects never seen before, helping to answer fundamental questions about the origins of planets, stars, and galaxies. SDO began sending back amazing images of the sun that will help us understand our neighbor and its effects on our planet and our communications systems. In September 2010, the latest Geostationary Operational Environmental Satellite, GOES-15 (also known as GOES-P), was accepted into service. It is designed to watch for storm development and weather conditions on Earth, relay communications, provide search-and-rescue support, and also provide additional capacity for our Nations' weather observing system.

Exploration Systems successfully tested the Ares 1-X for a two-minute powered flight. Results from this test will be helpful in developing the next generation of American spaceflight vehicles that could take humans beyond low-Earth orbit. Our Lunar Reconnaissance Orbiter helped us map the Moon and transform our understanding of it. Aeronautics completed the first phase of the X48-B Low Speed Flight Test Program of a Hybrid wing body aircraft, which is intended to reduce environmental impacts associated with aviation. NASA engineers and scientists tested new rocket motors, moved forward on aviation technologies to make air travel safer and cleaner, and worked with students around the country to help widen the pipeline of future leaders.

In June 2010, NASA launched its Summer of Innovation program, in support of the President's Educate to Innovate campaign for excellence in science, technology, engineering, and mathematics (STEM) education. Our first round of activities gave students in Wyoming, Idaho, Massachusetts, and New Mexico hands-on experience with space missions and science experiments. In FY 2011, we will continue to expand this important work to help develop students' interest in the core STEM disciplines. In addition, NASA awarded cooperative agreements to organizations across the United States to enhance learning through the use of NASA's Earth Science resources. The selected organizations include colleges and universities, nonprofit groups, and community college representatives.

As Administrator, one of my key responsibilities defined in the Space Act of 1958 (as amended) is to "provide for the widest practicable and appropriate dissemination of information concerning (NASA's) activities and the results thereof." As such, NASA embraces the White House's Open Government initiative calling on executive branch agencies to become more open and accountable. From making our open source software development more collaborative to creating a cloud computing platform, or making our social networks easily accessible and conducive to interaction, NASA is taking many steps to implement this openness in all of its activities. Also worthy of note is NASA's successful initiative to fund, track, and report on its accomplishment toward the goals and objectives of the American Recovery and Reinvestment Act (Recovery Act). NASA received $1,050 million of Recovery Act funding in fiscal year 2009 ($1,002 million Direct Appropriation and $48 million Reimbursable Authority), all of which has been obligated on projects to support the Nation's economic recovery and advance NASA's research mission. The Agency received an additional $4 million in Recovery Act Reimbursable Authority in FY 2010.

Although NASA was unable to achieve the Agency's Strategic Goal to retire the Space Shuttle by the end of FY 2010, the Agency plans to retire the Space Shuttle within the next year. Despite a year of transition and uncertainty, on September 29, 2010, the United States Congress voted resoundingly to endorse a clear path forward for NASA. Drawing on the ambitious plan for our Agency laid out by President Barack Obama, the Congress approved the National Aeronautics and Space Administration Authorization Act of 2010, which was signed by the President on October 11, 2010. This Act helps put the U.S. space program on a more sustainable trajectory that will lead to greater technological capabilities for our Nation, a new commercial space transportation industry, deeper international partnerships, and missions that will help inspire a new generation of Americans. With this new direction, we will also extend the life of the ISS, expand our investments in green aviation, Earth observation and education, and work to create thousands of new jobs in a vibrant, forward-looking economy.

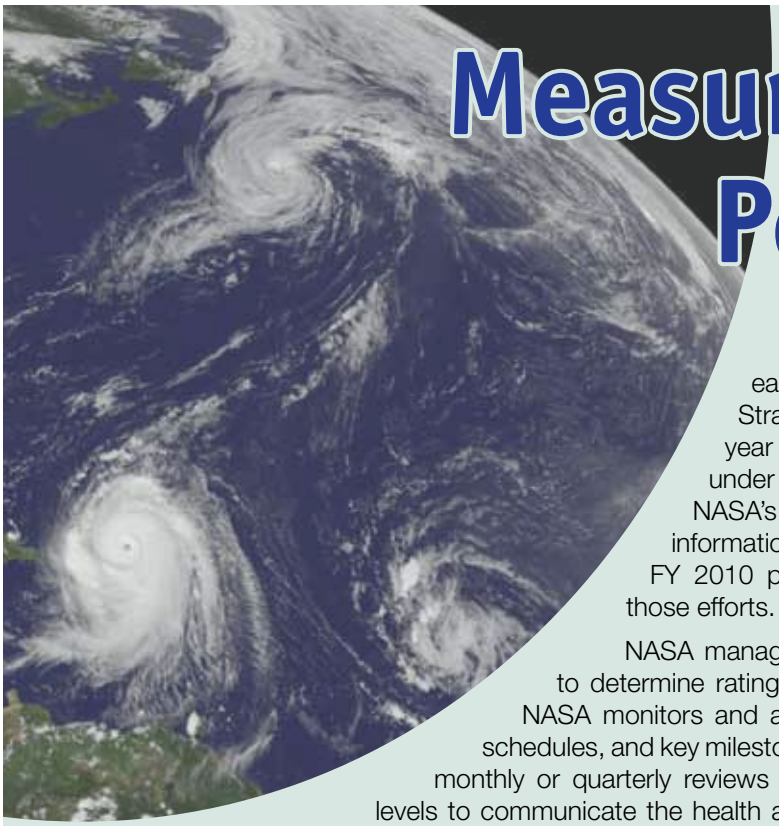
NASA makes every effort to ensure that performance data are subject to the same attention to detail as is devoted to our scientific and technical research. With this in mind, I can provide reasonable assurance that the performance data in this report are reliable and complete. Any data limitations are documented explicitly in the report.

In addition, NASA accepts the responsibility of accounting for and reporting on its financial activities. During FY 2010, NASA resolved the one remaining prior year internal control material weakness. The successful resolution of the prior year material weakness—Controls over Legacy Property, Plant, and Equipment related to valuation of legacy assets—is a result of extensive management involvement across the Agency. This achievement resulted from a sound system of financial controls and adherence to our Comprehensive Compliance Strategy and our Continuous Monitoring Program. In addition, we are now in compliance with the Federal Financial Management Improvement Act. Based on the results of this year's efforts, I am able to provide reasonable assurance that this report's financial data are reliable and complete.

My goal and focus, as NASA Administrator, is to continue to foster NASA as an exceptional resource for this Nation while keeping a sharp eye on our core values. We must always strive to find innovative ways to use NASA's missions to enhance our Nation's educational, scientific, and technological capacity.

Charles F. Bolden, Jr.
Administrator

# Detailed Performance



# Measuring NASA's Performance

NASA creates an annual performance plan for each fiscal year to work toward achieving NASA's Strategic Goals. The performance plan includes multi-year Outcomes and Annual Performance Goals (APGs) under each Strategic Goal and Sub-goal included in NASA's Strategic Plan. This section provides detailed information on NASA's performance on the Agency's FY 2010 performance plan and the cost associated with those efforts.

NASA managers use both internal and external assessments to determine ratings for multi-year Outcomes and APGs. Internally, NASA monitors and analyzes each program's adherence to budgets, schedules, and key milestones. The managers provide these analyses during monthly or quarterly reviews at the Center, Mission Directorate, and Agency levels to communicate the health and performance of their programs and projects. Based on the ratings, the managers formulate appropriate follow-up actions.

External advisors, like the NASA Advisory Council, the National Research Council, and the Aerospace Safety Advisory Panel, assess program content and direction. Also, experts from the science community, coordinated by NASA's Science Mission Directorate, review the Agency's progress toward meeting performance measures under Sub-goals 3A through 3D.

Many of the programs and projects mentioned in NASA's performance measures are either robotic or human spaceflight missions. For more information on the missions mentioned in the PAR, please see *NASA's Missions at a Glance*, located in the Other Accompanying Information section of this document.

## A Reader's Guide to NASA's Detailed Performance Data

NASA's detailed performance data is organized by the Strategic Goals and Sub-goals. Each Strategic Goal and Sub-goal contains the following information.

### Summary of Performance

Each Strategic Goal or Sub-goal section presents a summary of performance ratings for the multi-year Outcomes and APGs that support the goal. It also provides the expenditures associated with those activities.

### Benefits

This narrative explains the value of work toward the Strategic Goal or Sub-goal, from gains within the Agency to benefits for academia, the public sector, and government.

### Risks

Risk assessments are a regular part of NASA's review process. In this portion, NASA outlines and describes the primary concerns facing management with respect to cost, schedule, technical, or programmatic issues as they may affect individual missions, programs, or the Agency as a whole.

Image above: On August 30, 2010, the Geostationary Operational Environmental Satellite 13 (GOES-13) captured this image of Hurricane Danielle heading for the north Atlantic (top center), Hurricane Earl with a visible eye hitting the Leeward Islands (left bottom), and a developing tropical depression (lower right edge). (Credit: NASA/NOAA GOES Project)

## Performance Measure Descriptions, Ratings, and Trends

Each Outcome is a multi-year performance target designed to support the overarching Strategic Goal or Sub-goal. The description explains the activities completed in FY 2010 to meet the Outcome. NASA assigns ratings to these Outcomes on a yearly basis, and provides the current rating along with previous years' ratings to show trends in performance. While NASA rates the Outcome on a yearly basis, the rating takes into account past performance and future work. Management uses the scale below to assign ratings to the Outcomes based on their internal and external assessment results.

Every APG supports a multi-year Outcome. Although the APG is annual, it may be repeated several years in a row. NASA assigns ratings to these APGs on a yearly basis, and provides the current rating along with previous years' ratings to show trends in performance. In some cases, an APG may support more than one Outcome, and will be shown multiple times. Management uses the scale below to assign ratings to APGs based on their internal and external assessment results.

For any unmet performance measure in FY 2010, NASA managers are responsible for providing a reason for not achieving the measure and plans for reaching the measure in the future. The FY 2011 PAR will include an update to this year's Performance Improvement Plans, explaining activities and decisions that satisfy the plan set forth in FY 2010.

| What do the color ratings mean? | | |
|---|---|---|
| **Color** | **Multi-year Outcome Rating** | **Annual Performance Goal Rating** |
| **Green** | NASA achieved most APGs under this Outcome and is on-track to achieve or exceed this Outcome. | NASA achieved this APG. |
| **Yellow** | NASA made significant progress toward this Outcome, however, the Agency may not achieve this Outcome as stated. | NASA failed to achieve this APG, but made significant progress and anticipates achieving it during the next fiscal year. |
| **Red** | NASA failed to achieve most of the APGs under this Outcome and does not expect to achieve this Outcome as stated. | NASA failed to achieve this APG and does not anticipate completing it within the next fiscal year. |
| **White** | This Outcome was cancelled by management directive or is no longer applicable based on management changes to the APGs. | This APG was canceled by management directive and NASA is no longer pursuing activities relevant to this APG, or the program did not have activities relevant to the APG during the fiscal year. |

## Trending Information

If an APG is new in FY 2010, there will be no previous ratings available. The table below explains other trending information.

| | |
|---|---|
| **None** | Although NASA may have conducted work in this area, management did not include a performance measure for this work in the fiscal year's performance plan. |
| **7ES11 Green**<br>**7ES12 Green** | In prior years where data is available, NASA notes the applicable Outcome or APG reference number and rating to provide performance trends. In some cases, an APG may track to more than one performance measure in past performance years. |

# *Additional Information*

## Uniform and Efficiency Measures

NASA uses Uniform and Efficiency Measures to track the performance of management areas such as cost, schedule, and project completion. A table provides these measures, with current and previous ratings for trending, organized by NASA's budget Themes.

## FY 2009 Performance Plan Update

The FY 2009 Performance Improvement Plan Update reports activities and progress achieved during FY 2010 to resolve unmet measures from FY 2009.

# Strategic Goal 1

## Fly the Shuttle as safety as possible until its retirement, not later than 2010.

| Summary of Ratings for Strategic Goal 1 | |
|---|---|
| 2 Outcomes | 5 APGs |
| Green = 1 | Green = 3 |
| Yellow = 1 | Yellow = 2 |
| Red = 0 | Red = 0 |
| White = 0 | White = 0 |

| FY 2010 Cost of Performance (Dollars in Millions) |
|---|
| $4,678.5 |

The Space Shuttle has supported NASA's Mission for nearly 30 years, carrying crew and cargo to low Earth orbit, performing repair, recovery, and maintenance missions on orbiting satellites, providing a platform for conducting science experiments, and supporting construction of the International Space Station (ISS).

NASA has pushed back the planned retirement date for the Space Shuttle fleet until FY 2011 in order to ensure the completion of ISS. Until then, the Agency will demonstrate NASA's most critical value, safety, by promoting engineering excellence, maintaining realistic flight schedules, and fostering internal forums where mission risks and benefits can be discussed and analyzed freely.

# Benefits

The Space Shuttle is recognized around the world as a symbol of America's space program, and the Nation's commitment to space exploration. NASA's Space Shuttle Program has inspired generations to pursue dreams and careers in science, technology, engineering, and mathematics. The program directly benefits the Nation by advancing national security and economic interests in space and by spurring technology development in critical areas such as navigation, computing, materials, and communications.

# Risks to Achieving Strategic Goal 1

The Space Shuttle Program faces two main challenges. First, NASA must maintain the skilled workforce and critical assets needed to safely complete the Space Shuttle manifest. Second, NASA must manage the process of retiring the Shuttle and transitioning or disposing of Space Shuttle assets and capabilities when they are no longer needed for safe mission execution of the Shuttle or for other Agency use. Because of the size, complexity, and geographic dispersion of the program's assets, transition and retirement has required careful planning so as to not interfere with safe mission execution and with minimal impact to other Agency activities.

In addition to the sheer size of asset disposition activities, the Agency must cost-effectively manage and protect the Space Shuttle capabilities needed to satisfy the Agency's goal of flying out the manifest and completing assembly of the ISS. The program also plays a key role in coordinating the smooth transition from current Space Shuttle operations to the next generation of exploration activities, thereby enabling new U.S. human spaceflight capabilities that will extend exploration and permanent human presence beyond low Earth orbit.

Photo above: Space Shuttle *Atlantis* (STS-132) launches in a plume of smoke from NASA Kennedy Space Center on May 14, 2010. On its last planned flight, *Atlantis* delivered to the ISS the Russian-built Mini Research Module-1, which will provide additional storage space and a new docking port for Russian Soyuz and Progress spacecraft. (Credit: NASA/S. Joseph and K. O'Connell)

## *Outcome 1.1: Assure the safety and integrity of the Space Shuttle workforce, systems and processes, while flying the manifest.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |

Credit: NASA

On July 8, 2010, a crowd follows External Tank 138 as it leaves the Michoud Assembly Facility in New Orleans and begins its trip to the Kennedy Space Center in Florida. The last Space Shuttle tank produced at the facility, it is destined to support the STS-134 (*Endeavour*) launch. The day featured an event to commemorate 37 years of successful tank deliveries, as well as the final external tank's rollout.

**Space Shuttle flies four successful missions to the International Space Station**

The Space Shuttle Program successfully completed all mission objectives in FY 2010. NASA safely carried out four assembly and logistics flights to ISS; significantly enhancing the facilities and capabilities of the ISS. In preparation for Space Shuttle retirement, Space Shuttle *Atlantis* completed its last planned mission in May 2010 after delivering a new Russian module, batteries and other equipment and supplies to the ISS. During its lifetime, *Atlantis* flew 32 missions and traveled a total of more than 120 million miles.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Achieve zero Type-A (damage to property at least $1 million or death) or Type-B (damage to property at least $250 thousand or permanent disability or hospitalization of three or more persons) mishaps in FY 2010. | 7SSP1 Green | 8SSP01 Green | 9SSP1 Green | 10SSP01 Green |
| Complete 100% of all mission objectives for all Space Shuttle missions in FY 2010 as specified in the Flight Requirements Document for each mission. | 7SSP2 Green | 8SSP02 Green | 9SSP2 Green | 10SSP02 Green |

## *Outcome 1.2: By December 31, 2010, retire the Space Shuttle.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Yellow |

Credit: NASA/J. Pfaller

This long-range view shows equipment at the Kennedy Space Center's Launch Pad 39B dismantling the rotating service structure (RSS). Crews put sand, reinforcing steel, and large wooden mats under the RSS to protect the structure's concrete from falling debris during deconstruction. Starting in 2009, the structure at the pad was no longer needed for NASA's Space Shuttle Program, so it is being restructured for future use.

**NASA prepares for Space Shuttle retirement**

In FY 2010, NASA continued to prepare for the final Space Shuttle flights in November 2010 and February 2011 by producing and delivering major Space Shuttle hardware elements, including the last Solid Rocket Boosters and External Tanks. NASA also completed the Shuttle Transition Property Assessment to identify Space Shuttle assets that could still be used by the Agency in the future and to transfer assets no longer needed by NASA to interested organizations like museums and universities. As the Space Shuttle fleet approaches retirement, the Agency is directing available Space Shuttle personnel, assets, and knowledge toward the development and support of new hardware, technologies, and capabilities for human space exploration.

**Why NASA is not on track to achieve Outcome 1.2 as stated:** The yellow rating for Outcome 1.2 reflects an adjusted mission schedule that postpones Shuttle retirement activities in response to an Administration policy decision to extend Shuttle flights beyond 2010 to support the completion of the International Space Station.

**Plans for achieving Outcome 1.2:** Based on the extended mission schedule, NASA plans to retire the Space Shuttle in 2011.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Complete close-out and transfer plans for all remaining Space Shuttle flight hardware elements and other major Space Shuttle property assets, including the disposition plans for the Orbiters and the means by which significant gaps in human spaceflight operations capabilities will be managed if needed to support future activities. | None | None | None | 10SSP03 Yellow |
| Complete 100% of the Transition Property Assessment for Space Shuttle Program property by no later than the second quarter of FY 2010. | None | None | None | 10SSP04 Green |
| With the Constellation Program, complete and deliver one workforce transition strategy report update to Congress in FY 2010. | None | None | None | 10SSP05 Yellow |

**Why NASA did not achieve APG 10SSP03:** The Agency's decision to extend Space Shuttle flights into 2011 and the uncertainty regarding the future of the Constellation Program caused a delay in finalizing Shuttle asset disposition plans and resolving the human spaceflight gap.

**Plans for achieving 10SSP03:** Disposition plans for the Orbiters will be completed once NASA announces final display locations. NASA plans to resolve funding gaps for human spaceflight capabilities through the FY 2012 budget development process.

**Why NASA did not achieve APG 10SSP05:** Development of Workforce Transition Strategy reports has been rescheduled pending direction to the Agency following the release of the FY 2011 President's Budget Submit, the proposed transition of the Constellation Program, and identification of future work. In the FY 2011 budget process, the President proposed to Congress that the Constellation Program be transitioned to a new set of programs, and NASA adjusted its spending on the program consistent with its budget request and with the Appropriation provided by Congress for FY 2010.

**Plans for achieving 10SSP05:** The plan is pending decision of the proposed transition of the Constellation Program.

# Strategic Goal 2

## Complete the International Space Station in a manner consistent with NASA's International Partner commitments and the needs of human exploration.

| Summary of Ratings for Strategic Goal 2 | |
|---|---|
| 3 Outcomes | 10 APGs |
| Green = 3 | Green = 9 |
| Yellow = 0 | Yellow = 1 |
| Red = 0 | Red = 0 |
| White = 0 | White = 0 |

| FY 2010 Cost of Performance (Dollars in Millions) |
|---|
| $3,711.3 |

Built and operated using state-of-the-art science and technology, the International Space Station (ISS) remains a vital aspect of NASA and its program of exploration. As of September 2010, there have been over a hundred flights to the ISS, including flights for assembly, crew rotation, and logistical support. When assembly is complete in 2011, the ISS will be composed of approximately one million pounds of hardware brought to orbit over the course of more than a decade.

## Benefits

The ISS, the largest crewed spacecraft ever built, provides an environment for developing, testing, and validating next generation technologies and processes, which are needed to support NASA's plans to send human explorers deeper into space. The ISS is a test bed for exploration technology and process experiments, and provides opportunities for research in fundamental physics, biology, materials sciences, and medicine. Its equipment and location provide a unique platform for Earth observations, microgravity research, and investigations into the long-term effects of the space environment on human beings. Crewmembers test processes for repairing equipment in microgravity, conducting spacewalks, and keeping systems operational over long periods of time. These capabilities are critical to future missions beyond low Earth orbit.

The ISS Program represents an unprecedented level of international cooperation with many nations providing the resources and technologies to build and keep the ISS operational. These international partnerships have increased cooperation and goodwill among participating nations and will continue to serve as a model for future space cooperation.

## Risks to Achieving Strategic Goal 2

Strategic Goal 2 has two primary risks: the Space Shuttle Program's ability to carry out the ISS manifest and complete assembly operations, and the continued operation of the systems that support the six-person crew capability.

Photo above: An STS-132 crewmember aboard *Atlantis* took this photograph of the ISS on May 23, 2010, as the Space Shuttle undocked and began separation on its return to Earth. (Credit: NASA)

## *Outcome 2.1: By 2010, complete assembly of the U.S. On-orbit Segment; launch International Partner elements and sparing items required to be launched by the Shuttle; and provide on-orbit resources for research to support U.S. human space exploration.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |

Credit: NASA

In February 2010, Kathryn Hire, STS-130 mission specialist, works in the newly-installed ISS Cupola. The Space Shuttle crewmembers helped install the Cupola, a European Space Agency-provided module that will provide clear views of activities outside the ISS and spectacular views of Earth.

### ISS construction nearing completion

While NASA was unable to launch every piece of hardware planned for the ISS in FY 2010, a Russian research module and EXpedite the PRocessing of Experiments to the Space Station (ExPRESS) Logistics Carriers (ELC) were launched. Delays in the Shuttle missions driven by technical issues with the Alpha Magnetic Spectrometer (AMS) experiment caused delays in the launch of the two remaining ELCs, AMS, and the Permanent Multipurpose Module (PMM). The payloads are now scheduled to be launched during the first half of FY 2011.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Based on the actual Space Shuttle flight rate, number of remaining Shuttle flights, and the discussions with the International Partners, update the agreed-to ISS assembly sequence and transportation plan as necessary. | 7ISS1 Green | 8ISS01 Green | 9ISS1 Green | 10ISS01 Green |
| Accomplish a minimum of 90% of the on-orbit research objectives as established one month prior to a given increment. | 7ISS2 Green | 8ISS02 Green | 9ISS2 Green | 10ISS02 Green |
| Per the final configuration agreed to by the International Partners, fly the ISS elements and logistics baselined for FY 2010. | 7ISS3 Green | 8ISS03 Green | 9ISS3 Green | 10ISS03 Yellow |
| Provide increased ISS capability and utilization by integrating ISS elements, payloads, and spares including the EXPRESS Logistics Carriers 1 through 4, Cupola, Node 3, Multipurpose Pressurized Logistics Module, a COTS demonstration, and Mini-Research Module. | None | 8ISS04 Green | 9ISS4 Yellow | 10ISS04 Green |

**Why NASA did not achieve APG 10ISS03:** Due to technical difficulties and unforeseen delays, NASA was unable to fly all ISS elements and logistics planned for FY 2010.

**Plans for achieving 10ISS03:** Consistent with an Administration policy decision, NASA has revised the Shuttle manifest and related logistics to accommodate the delays experienced in FY 2010 and anticipates ISS completion in FY 2011.

## *Outcome 2.2: Through 2015, provide the on-orbit capability to support an ISS crew of 6 crewmembers.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |

Credit: NASA

Tracy Caldwell Dyson, Expedition 23 flight engineer, poses for a photo while holding Power and Data Grapple Fixture (PDGF) hardware in the ISS Harmony node. PDGFs allow the robotic manipulator arm Canadarm2 to attach, pick up, manipulate, and detach from various locations around the exterior of the ISS.

**A bigger station, a bigger crew**

NASA fully met the goal of providing support for a crew of 6 during FY 2010 as crewmembers from Expeditions 19 through 25 rotated to and from the ISS. NASA also worked with its International Partners and commercial cargo suppliers to develop plans for maintaining a crew of 6 on ISS through at least 2015. This will be accomplished with a combination of U.S. commercial, Russian, European, and Japanese logistics missions.

NASA fully met the goal of providing support for a six-passenger crew during FY 2010 as crewmembers from Expeditions 19 through 25 rotated to and from the ISS.

Expeditions 23 and 24 finished the laboratory, delivering additional facilities to enable full use of the International Space Station for research, technology development, and education. With nearly 130 integrated investigations involving the work of nearly 400 scientists around the globe; scientific throughput has quadrupled during the transition from ISS assembly to the era of utilization.

NASA also worked with its international partners and commercial cargo suppliers to develop plans for maintaining a six-passenger crew on ISS through at least 2015. This will be accomplished with a combination of U.S. commercial, Russian, European, and Japanese logistics missions.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Achieve zero Type-A (damage to property at least $1 million or death) or Type-B (damage to property at least $250 thousand or permanent disability or hospitalization of three or more persons) mishaps in FY 2010. | None | None | None | 10ISS05 Green |
| In concert with the International Partners, maintain a continuous crew presence on the ISS by coordinating and managing resources, logistics, systems, and operational procedures. | 7ISS5 Green | 8ISS06 Green | 9ISS6 Green | 10ISS07 Green |
| Deliver 100% of planned on-orbit resources (including power, data, crew time, logistics, and accommodations) available to support research. | None | None | None | 10ISS08 Green |

## *Outcome 2.3: Conduct basic and applied biological and physical research to advance and sustain U.S. scientific expertise.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| None | Green | Green | Green |

Credit: NASA

Expedition 23 flight engineer T.J. Creamer poses for a photo next to the Microgravity Science Glovebox, an enclosed facility used to conduct experiments that are messy or potentially hazardous. The astronauts use it to conduct most of the fluid dynamics and flame experiments.

**NASA space experiments working to improve life on Earth**

In FY 2010, NASA completed and launched new experimental facilities for the ISS and used ISS facilities and the Space Shuttle to conduct numerous scientific investigations focused on the fundamental laws governing natural processes while also enhancing the knowledge required to prepare NASA for future space missions. Some of the scientific investigations conducted in support of this Outcome include:

- The Capillary Channel Flow experiment (CCF): This experiment examined the limitations of fluid dynamics in space and will help researchers improve a wide range of spacecraft fluid systems.
- The Dynamic Selection of Interface Patterns (DSIP): This experiment focused on the dynamics that lead to uniform, reproducible three-dimensional pattern formation during the solidification of alloys. Understanding these dynamics could improve many industrial applications that rely on pattern formation for controlling microstructure in high temperature, high strength alloys.
- The Gravitational Effects on Biofilm Formation During Space Flight (Micro-2) experiment examined how gravity alters biofilm (an aggregation of microorganisms) formation with the goal of developing new strategies to reduce their impact on crew health and to minimize the harmful effects of biofilms on materials in space and on Earth.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Deliver 2 out of 3 of the following exploration technology payloads to SOMD for launch to the ISS: 1) Boiling Experiment Facility; 2) Capillary Channel Flow, or several test vessels of the Capillary Flow Experiment-2; or 3) Conduct the tests for the Flame Extinguishment Experiment exploration payload on ISS. | None | 8AC01 Green | 9AC1 Green | 10AC01 Green |
| Conduct 3 out of 4 of the following nonexploration experiments on the ISS: 1) Dynamical Selection of Interface Patterns; 2) Two samples from Microstructure Formation in Castings of Technical Alloys under Diffusive and Magnetically-Controlled Convective Conditions (MICAST)/Columnar-Equiaxed Transition in Solidification Processing experiment; 3) Binary Critical Aggregation Test-5; or 4) Investigating the Structures of Paramagnetic Aggregates from Colloidal Emulsions-3. | None | None | 9AC2 Green | 10AC02 Green |
| Develop for flight two ISS/Shuttle/Free Flyer payloads: Develop the Animal Enclosure Module for launch on the Space Shuttle, to conduct immunology research on rodents; and develop a nano-satellite as a secondary Free Flyer payload to conduct fundamental biological research. | None | None | None | 10AC03 Green |

# Sub-Goal 3A

## Study Earth from space to advance scientific understanding and meet societal needs.

| Summary of Ratings for Sub-Goal 3A | |
|---|---|
| 7 Outcomes | 17 APGs |
| Green = 7 | Green = 14 |
| Yellow = 0 | Yellow = 3 |
| Red = 0 | Red = 0 |
| White = 0 | White = 0 |

| FY 2010 Cost of Performance (Dollars in Millions) |
|---|
| $2,133.6 |

NASA has pursued its unique mission in Earth science, which is to expand human knowledge of Earth through space activities. This mission is specifically mandated by NASA's establishing legislation, the National Aeronautics and Space Act of 1958. Indeed, half a century of progress in spaceflight and advances in space-related technology have steadily changed the perception of Earth. Global satellite measurements of key characteristics have given rise to a profound new understanding of Earth as a system of interconnected parts.

NASA pioneered what is now called Earth System Science. From the vantage point of space, NASA currently focuses on studying atmospheric composition, weather, climate variability and change, water and energy cycles, carbon cycle and ecosystems, and Earth surface and interior. Over the past 50 years, the world's population has doubled, world grain supplies tripled, and total economic output grew sevenfold. NASA now observes that expanding human activities affect half the entire land surface of Earth and are altering world atmospheric composition, oceans, ecosystems, and ice masses.

NASA has also observed how international agreements can begin to reverse some of those trends, as in the case of industrially produced chlorofluorocarbons. By understanding these varying processes and their interaction, scientists can make predictions about the Earth system, quantitatively test those theories against satellite observations, and eventually improve forecasting in order to better inform resource management decisions and policies of governments at all levels.

Thus, fundamentally this Sub-goal answers the question: How is Earth changing and what are the consequences for life on Earth? In January 2007, the National Research Council (NRC) released its first Earth science decadal survey, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond* (available online at *http://www.nap.edu/catalog.php?record_id=11820*). This decadal survey describes Earth science as one of the greatest intellectual challenges facing humanity and outlines a program of scientific discovery and development of applications that will enhance economic competitiveness, protect life and property, and assist in the stewardship of the planet for this and future generations. NASA has embarked on the implementation of the Decadal Survey recommendations, while continuing its critical contributions to national programs and interagency

Image above: Arctic sea ice and seasonal land cover change are shown on March 30, 2010, the day before sea ice reached its 2010 maximum extent. Sea ice coverage over the Arctic Ocean oscillates over the course of a year, growing through winter and reaching a maximum extent by February or March. This year, Arctic sea ice grew to levels beyond those measured in recent years but slightly below average when compared to the 30-year satellite record. (Credit: NASA/Goddard Space Flight Center Scientific Visualization Studio)

collaborations. For example, the NASA Earth Science Program is the largest contributor to the congressionally mandated U.S. Global Change Research Program (USGCRP).



# Benefits

Much of the science community's present state of knowledge about global change, including many of the measurements and a significant fraction of the analyses that serve as the foundation for the assessment reports of the Intergovernmental Panel on Climate Change (IPCC) and the quadrennial ozone assessment by the World Meteorological Organization, is derived from NASA's Earth Science Program. For example, using data from Earth observing satellites, NASA-supported researchers are: discovering the rapidity of sea ice depletion in the Arctic cover and ice sheet motions in the Arctic and Antarctic; quantifying short-term and long-term changes to Earth's protective shield of stratospheric ozone, including the positive impacts of the Montreal Protocol; establishing relationships between increasing upper ocean temperature and decreasing primary production from the phytoplankton that form the base of the oceans' food chain; using a fleet of satellites flying in formation (the A-Train) to study the effects of aerosols in the atmosphere on cloud formation and cloud cover; and using rainfall, vegetation, and other data to help predict food shortage conditions in developing countries.

By flying satellites in the A-Train formation, NASA is capable of making unique, global, near-simultaneous measurements of aerosols, clouds, temperature and relative humidity profiles, and radiative fluxes. Similarly, the use of satellites, aircraft, and ground-based monitoring stations provides NASA effective calibration of new measuring capabilities and provides unprecedented views into numerous phenomenon, such as the origin of storms. This vital research conducted by NASA and its partners, other government agencies, academia, non-profit organizations, industry, and international organizations helps the Nation manage environmental and agricultural resources and prepare for natural disasters. With its operational partners, NASA applies the resulting data and knowledge with the Agency's operational partners to improve their decision-making in societal need areas such as public health, aviation, water management, air quality, and energy.

NASA's Earth Science Program also supports the development of new sensors and instruments, advanced communications systems, and computer technologies.

Near-real-time measurements from NASA research missions, such as the Tropical Rainfall Mapping Mission (TRMM), the Quick Scatterometer (QuikSCAT), and the Atmospheric Infrared Sounder instrument on the Aqua mission are used routinely by the National Oceanic and Atmospheric Administration (NOAA) and other U.S. and international agencies to improve weather forecasting. NASA works closely with NOAA and the other Federal agencies to transition satellite research measurement capabilities to long-term operations, as appropriate.

# Risks to Achieving Sub-goal 3A

The Earth Science Division, along with NASA's other Science divisions, continues to be concerned with the increased cost and the reduced availability of expendable launch vehicle (ELV) options. Over the course of the last decade, the Delta II has been the workhorse for launching many robotic mid-sized spacecraft. Without this option, NASA has access only to costlier evolved ELVs (Delta IV, Atlas V), which were designed to launch payloads larger than planned for many of the Earth Science missions identified in the NASA Science Plan. Possible cost growth in the evolved ELV class is an additional source of concern. These problems cannot be avoided until new commercial launch vehicles become available, potentially reducing the cost of launching missions.

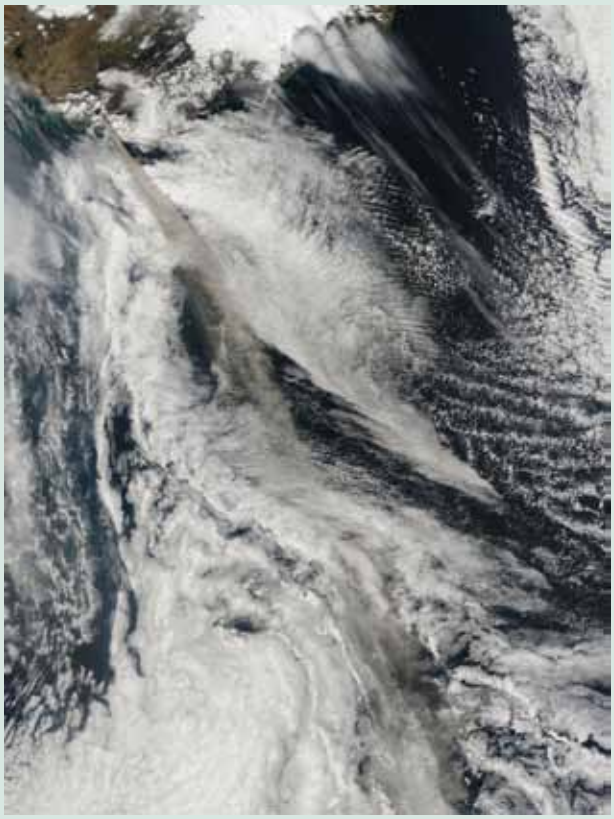
## *Outcome 3A.1: Progress in understanding and improving predictive capability for changes in the ozone layer, climate forcing, and air quality associated with changes in atmospheric composition.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |

**NASA watches an Icelandic giant awaken**

On March 20, 2010, Iceland's Eyjafjallajökull volcano (pronounced "Aya-fyatla-jo-kutl") awakened for the first time in 120 years, and NASA's Earth observing satellites were watching and collecting data.

Through its fleet of satellite assets, NASA is able to rapidly generate and broadly disseminate imagery and data products on the location, heights, and densities of ash plumes and related hazards. NASA demonstrated reliable and accurate detection of volcanic ash clouds using observations of sulfur dioxide ($SO_2$) from the Ozone Monitoring Instrument (OMI) onboard the NASA Aura satellite.



Credit: NASA/MODIS Rapid Response Team

Iceland's Eyjafjallajokull volcano was still streaming ash as NASA's Aqua satellite flew overhead on May 9. Iceland and the volcano are located in the top left part of this satellite image, with the ash and steam trailing a brown plume as it blew in a south-southeast direction over the Atlantic Ocean. The ash was estimated at heights of 30,000 feet. The brighter white color is snow and ice on Iceland's land surface. This and other images of Iceland's volcano are available at: *http://www.nasa.gov/topics/earth/features/iceland-volcano-plume-archive1.html*.

Sulfur dioxide is a reliable marker for fresh ash clouds from explosive magmatic eruptions, as it provides a clear discrimination between volcanic plume and ordinary clouds. Since volcanic eruptions are essentially the only large sources of stratospheric $SO_2$, false alarms are non-existent. Satellite observations of $SO_2$ thus assist operational agencies to identify and locate volcanic ash clouds, in particular during the first few days after an eruption. In general, the ash in a volcanic plume will drop due to gravity effects faster than the $SO_2$, so that some distance away from the volcano the ash and $SO_2$ clouds may be separated.

By the end of May, considerable steam had been coming from the crater, but monitoring the eruption became difficult because of windblown ash. NASA provided atmospheric composition data, including ash plume height and optical depth maps from The Earth Observing System (EOS) Multi-angle Imaging SpectroRadiometer (MISR) and Moderate Resolution Imaging Spectroradiometer (MODIS) instruments, respectively, to the international advisory groups that feed scientific input to the European operational Volcanic Ash Advisory Center. The MISR and MODIS, which were capable of detecting fires and the heat of lava flows, often were the only way to track the eruptions. The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) satellite recorded a vertical profile of the atmosphere, which revealed the altitude of the ash clouds. NASA, in collaboration with NOAA, provides information on volcanic $SO_2$ and ash aerosols from OMI every three hours after the data is acquired. This information is used to supplement data from NOAA's Operational Environmental Satellites. NOAA distributes these data online to its Volcanic Ash Advisory Centers (VAACs).

At the time of the latest eruption, $SO_2$ information was being made routinely available only for sectors covering the Americas and the Pacific, through the Anchorage and Washington Volcanic Ash Advisory Centers (VAACs). However, beginning on April 19, 2010, NASA began to provide this information for sectors covering Iceland and

Northwest Europe to the VAAC in London. This information is now being utilized in the formulation and validation of Volcanic Ash Advisories over Europe. These observations helped modelers in volcanic ash advisory centers improve forecasting models and issue more accurate warnings to pilots and others with aviation interests.

**Global Hawk takes flight for atmospheric science**

NASA and colleagues from the National Oceanic and Atmospheric Administration completed the first science campaign with the new NASA Global Hawk Unmanned Aircraft System. This campaign obtained over 100 hours of both in situ and remote sensing observations in the upper troposphere and lower stratosphere over the Pacific Ocean, Alaska, and Arctic Ocean. The flights directly sampled and measured greenhouse gases, ozone-depleting substances, aerosols, and constituents of air quality.

For more information on the Global Hawk Pacific campaign go to *http://www.nasa.gov/centers/dryden/research/GloPac/index.html*.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Demonstrate progress in understanding and improving predictive capability for changes in the ozone layer, climate forcing, and air quality associated with changes in atmospheric composition (based on measurements from presently orbiting NASA and non-NASA assets). Progress will be evaluated by external expert review. | 7ESS1 Green | 8ES01 Green | 9ES1 Green | 10ES01 Green |
| Conduct the flight program in support of this Outcome, as demonstrated by achieving mission success criteria for Aura. | None | None | None | 10ES03 Green |
| Develop missions in support of this Outcome, as demonstrated by completing the Pre-Ship Comprehensive Performance Test for Glory. | 7ESS8 Yellow | 8ES09 Yellow | 9ES3 Red | 10ES21 Yellow |
| Develop missions in support of this Outcome, as demonstrated by conducting the acquisition strategy meeting for the OCO-2 mission, defining the implementation and acquisition approach for the reconstituted mission. | 7ESS6 Yellow | 8ES04 Yellow | 9ES2 Green | 10ES22 Green |

**Why NASA did not achieve APG 10ES21:** The Glory Pre-Ship Comprehensive Performance Test began on September 17, 2010, but was not completed until October 4, 2010. The test was delayed primarily due to resolution of spacecraft hardware anomalies.

**Plans for achieving 10ES21:** The test was completed successfully on October 4, 2010.

## *Outcome 3A.2: Progress in enabling improved predictive capability for weather and extreme weather events.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |

**NASA puts the power of information in users' hands**

With its partners at NOAA weather forecast offices, NASA provides measurements from the Atmospheric Infrared Sounder (AIRS), Cloudsat/CALIPSO, Moderate Resolution Imaging Spectroradiometer (MODIS) and Advanced Microwave Scanning Radiometer–Earth Observing System (AMSR-E) to improve the skills of operational weather forecasts. Through the Short-term Prediction Research and Transition (SPoRT) center, NASA satellite observations are used by 15 National Weather Service (NWS) Weather Forecast Offices (WFOs) for severe weather forecasting.

SPoRT was established in 2002 to demonstrate the weather and forecasting application of real-time EOS measurements from NASA climate monitoring sensors. It has grown to be an end-to-end research to operations activity focused on the use of advanced NASA modeling and data assimilation techniques, now-casting, and unique high-resolution multispectral observational data to improve short-term weather forecasts. SPoRT provides a suite of over 30 products, unique weather forecasts, and weather analyses to 15 NWS forecast offices in the southeast U.S. The offices use the products to improve situational awareness leading to better forecasts and warnings.

Credit: NASA/J. Schmaltz, MODIS Land Rapid Response Team

A cloudless day in the central United States shows the colors characteristic of fall on October 5, 2010, when MODIS aboard the Aqua satellite passed overhead. Another feature often seen in fall are the numerous fires, visible from the thin line of smoke along the left side of the photo from fires burning along the lower Mississippi River valley. Fall is harvest time in this agricultural area, and the vegetation becomes dry and flammable. SPoRT is helping forecasters use MODIS to monitor fires and other hazards.

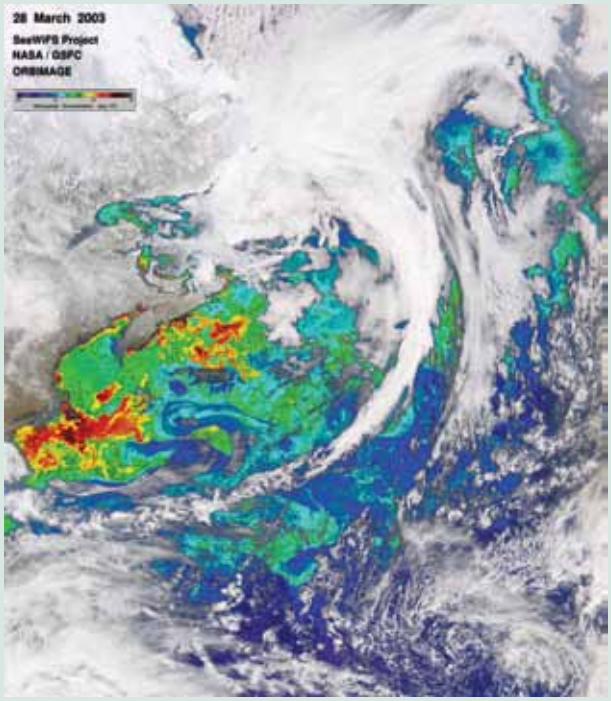
Recent activities have shown that the assimilation of AIRS radiance and profile data on a regional scale can provide consistent improvement in understanding the thermodynamic structure of the atmosphere in data void regions, leading to better short-term weather forecasts. A high resolution sea surface temperature composite product derived from MODIS and AMSR-E data has been demonstrated to make improvements in the prediction of coastal weather processes and tropical weather systems. The use of NASA observations to better model surface conditions (e.g., fluxes of heat and moisture) in the NASA Land Information System (LIS) has produced better regional weather forecasts. NASA data sets and advanced research capabilities are currently used by collaborating forecast offices and the broader weather community via the Weather and Research Forecast (WRF) Environmental Modeling System. Forecasters also benefit directly from real-time observations of low clouds and fog, snow cover imagery, sea surface temperatures, land surface temperatures, wildfire hot spots maps, and other unique NASA imagery and products covering regions void of more conventional data.

For more on SPoRT go to *http://weather.msfc.nasa.gov/sport/*.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Demonstrate progress in enabling improved predictive capability for weather and extreme weather events. Progress will be evaluated by external expert review. | 7ESS2 Green | 8ES02 Green | 9ES7 Green | 10ES04 Green |
| Develop missions in support of this Outcome, as demonstrated by completing the Global Precipitation Measurement (GPM) Critical Design Review (CDR). | None | 8ES06 Yellow | 9ES8 Yellow | 10ES06 Green |

## *Outcome 3A.3: Progress in quantifying global land cover change and terrestrial and marine productivity, and in improving carbon cycle and ecosystem models.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |




Credit: NASA/ORBIMAGE

The red and yellow colors in this image represent high chlorophyll concentrations in the sea's surface waters off the northeastern coast of Canada. Chlorophyll is a primary pigment found in phytoplankton. The green hues show moderately high chlorophyll concentrations, and blues represent low values. This image was produced using Sea-viewing Wide Field-of-view Sensor (SeaWiFS) data collected on March 28, 2003.

**NASA monitors microscopic ocean plants from orbit**

Around the globe, plants are the base of the food web. In the oceans, phytoplankton (microscopic plants) grow in the sunlit surface waters. Places where blooms are frequent often support thriving marine life. In FY 2010, scientists concluded that global ocean phytoplankton production can only be discerned in the satellite record with continued, long-term data collection.

The spring phytoplankton bloom is one of the most widespread changes in the oceanic biosphere, beginning just north of the Sargasso Sea and Bermuda and spreading northward toward Iceland. The best way to view this bloom is from space, using instruments that can discern the subtle changes in bloom color and concentration.

Phytoplankton influence global climate by regulating gases in the atmosphere. Like all plants, phytoplankton absorb carbon dioxide and release oxygen as they grow. When the phytoplankton die, a fraction of them sink to the ocean floor, carrying carbon with them. Over the course of Earth's history, the oceans have become the primary sink for atmospheric carbon dioxide. Since carbon dioxide is a greenhouse gas (it traps heat at Earth's surface), Earth would be a much warmer place without phytoplankton. In some areas, phytoplankton blooms are so abundant that their death and decomposition often robs the water of dissolved oxygen. As the plants die, they sink to the ocean floor where bacteria consume them. There is so much plant material that the bacteria use all of the oxygen available in the water before they finish breaking down the plants, creating a dead-zone in the water where fish cannot survive. Anaerobic bacteria, which do not require oxygen, take over in the decomposition process, releasing sulfur dioxide as a byproduct. The sulfur dioxide interacts with the ocean water to create solid sulfur and hydrogen sulfide, a poisonous gas, which eventually erupts to the surface, sometimes killing fish.

With phytoplankton production playing such a vital role in ocean health and global climate, it has become increasingly important to monitor the spring blooms. Scientists use these data to model near- and long-term effects on the ecology. The scientists determined that the existing ocean production satellite record is sufficient to determine that the cause of the traditional North Atlantic spring bloom of phytoplankton central to understanding and modeling the ecology of the oceans is different than as historically understood. They used NASA data to detail the mechanisms causing the spring bloom in the North Atlantic Ocean, a very productive and fisheries-rich area. Through modeling efforts incorporating a range of satellite products, they improved descriptions of carbon cycling in U.S. coastal waters and of physical mechanisms controlling the dominance of phytoplankton functional types in the global ocean.

For more information on this story go to *http://disc.sci.gsfc.nasa.gov/oceancolor/additional/science-focus/ocean-color/science_focus.shtml/nab.shtml*.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Demonstrate progress in quantifying global land cover change and terrestrial and marine productivity and in improving carbon cycle and ecosystem models. Progress will be evaluated by external expert review. | 7ESS3 Green | 8ES03 Green | 9ES10 Green | 10ES07 Green |
| Develop missions in support of this Outcome, as demonstrated by completing the Landsat Data Continuity Mission (LDCM) Confirmation Review. | None | None | 9ES11 Green | 10ES08 Green |
| Develop missions in support of this Outcome, as demonstrated by conducting the acquisition strategy meeting for the OCO-2 mission, defining the implementation and acquisition approach for the reconstituted mission. | 7ESS6 Yellow | 8ES04 Yellow | 9ES2 Green | 10ES22 Green |

## *Outcome 3A.4: Progress in quantifying the key reservoirs and fluxes in the global water cycle and in improving models of water cycle change and fresh water availability.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |

Credit: NASA/J. Allen, Earth Observatory

By the end of July 2009, California was well into its third dry year in a row, reducing vegetation cover, as shown here in an image made from data collected by NASA's Terra satellite. On average, the state's reservoirs were running low. The Westlands, reports National Public Radio, is the United State's biggest irrigated region. Water pumped into the region from the Sacramento and San Joaquin River Delta via the San Luis Reservoir supports farms where much of the nation's fruit, nuts, and produce are grown. Like many other places throughout the world, California faces difficult decisions about managing its limited water resources. The ability to predict drought and plan accordingly has become an important tool for regional and state governments.

**NASA creates good NEWS for Earth's energy and water cycle**

The cycling of energy and water has obvious and significant implications for the health and prosperity of society. The availability and quantity of water is vital to life on Earth and helps to tie together Earth's lands, oceans, and atmosphere into an integrated physical system. The NASA Energy and Water cycle Study (NEWS) has compiled the first-ever satellite-based energy and water cycle climatology.

The 10 year climatology includes monthly, continental, and oceanic averages of Earth's precipitation, evaporation, water vapor, and radiation balance. The radiation balance compares the amount of solar radiation coming into the atmosphere with infrared radiation emitted from Earth's surface, which either passes through the atmosphere into space or is absorbed and re-emitted by greenhouse gases in the atmosphere. This radiation balance warms the planet's surface. This new integrated global water and energy assessment is being used in conjunction with NASA's Modern Era Retrospective-Analysis for Research and Applications (MERRA) reanalysis to study and improve predictions of weather and climate variability. These integrated water and energy satellite studies also have provided insights to the mechanisms and severity of mid-western U.S. floods and droughts, helping to mitigate future damage caused by these extremes.

More about NEWS is available at *http://news.cisc.gmu.edu/*.

More about MERRA is available at *http://gmao.gsfc.nasa.gov/merra/*.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Develop missions in support of this Outcome, as demonstrated by completing Aquarius Operational Readiness Review (ORR). | None | 8ES10 Yellow | 9ES4 Green | 10ES02 Yellow |
| Develop missions in support of this Outcome, as demonstrated by completing the Global Precipitation Measurement (GPM) Critical Design Review (CDR). | None | 8ES06 Yellow | 9ES8 Yellow | 10ES06 Green |
| Demonstrate progress in quantifying the key reservoirs and fluxes in the global water cycle and in improving models of water cycle change and fresh water availability. Progress will be evaluated by external expert review. | 7ESS5 Green | 9ES05 Green | 9ES13 Green | 10ES09 Green |
| Develop missions in support of this Outcome, as demonstrated by completing the SMAP Preliminary Design Review (PDR). | None | None | 9ES14 Green | 10ES10 Yellow |

**Why NASA did not achieve APG 10ES02:** Due to delays in the development of the international partner's Mission Operations System, the ORR was not completed in FY 2010.

**Plans for achieving 10ES02:** A specific date has not been identified, but NASA estimates this to be in early 2011. However, any delays to the overall mission schedule could cause the ORR to move further.

**Why NASA did not achieve APG 10ES10:** The Soil Moisture Active and Passive (SMAP) mission PDR is currently scheduled for March 2011, consistent with the schedule presented at the mission's Initial Confirmation Review.

**Plans for achieving 10ES10:** Currently, all pre-cursor events (i.e., peer reviews, sub-system PDRs) are proceeding on or ahead of plan. However, a launch vehicle has not yet been selected for SMAP, and this could impact the scheduling of the PDR. NASA is addressing this issue, but it is not expected to be resolved until after March.

## NASA in the Spotlight

### *NASA Deploys Planes, Targets Satellites to Aid in Oil Spill Response*

This spring when U.S. disaster response agencies needed help monitoring the Deepwater Horizon BP oil spill in the Gulf of Mexico, NASA mobilized its many remote-sensing assets.

As part of the national response to the spill, NASA deployed its instrumented research aircraft the Earth Resources-2 (ER-2) to the Gulf on May 6. The Agency also made extra satellite observations and conducted additional data processing to assist the National Oceanic and Atmospheric Administration (NOAA), the U.S. Geological Survey (USGS), and the Department of Homeland Security monitor the spill. Researchers also measured changes in vegetation along the coastline and assessed where and how oil was affecting marshes, swamps, bayous, and beaches that are difficult to survey on the ground. The combination of satellite and airborne imagery helped NOAA forecast the trajectory of the oil and document changes in the ecosystem.

For more on this story go to *http://www.nasa.gov/topics/earth/features/oil_spill_er2_feature.html*.

Image above: Oil from the Deepwater Horizon spill laps around the mouth of the Mississippi River delta in this May 24, 2010, image from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument on NASA's Terra spacecraft. The oil appears silver, while vegetation is red. (Credit: J. Allen/NASA; U.S./Japan ASTER Science Team)

## *Outcome 3A.5: Progress in understanding the role of oceans, atmosphere, and ice in the climate system and in improving predictive capability for its future evolution.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Yellow | Yellow | Green | Green |

Credit: NASA

On August 5, 2010, an enormous chunk of ice, roughly the size of Manhattan, broke off the Petermann Glacier, along the northwestern coast of Greenland, visible near the center of this real-time image taken by NASA's Aqua satellite. The Petermann Glacier lost about one-quarter of its 70-kilometer-long (40-miles) floating ice shelf in a process called calving, when a large chunk of an iceberg breaks away. Icebergs calving off the giant glacier are not unusual—it has occasionally calved large icebergs—but the one from August is the largest to form in the Arctic since 1962. For more on IceBridge go to: *http://www.nasa.gov/mission_pages/icebridge/index.html*.

**IceBridge finds warm waters in Greenland glacier**

The Arctic Ocean is covered by a dynamic layer of sea ice that grows each winter and shrinks each summer, reaching its yearly minimum size each fall. Between March and May 2010, NASA's IceBridge mission completed a field campaign to monitor Greenland and Arctic sea ice, focusing on areas where glaciers and ice sheets have been undergoing rapid changes and finding warm water in surprising places.

IceBridge, which is bridging the gap between NASA's Ice, Cloud and Land Elevation Satellite (ICESat) I and II missions, is the largest airborne survey of Earth's polar ice ever flown. These flights are providing a yearly, multi-instrument look at the behavior of the rapidly changing features of the Greenland and Antarctic ice. Scientists are using the data to create an unprecedented three-dimensional view of the cryosphere, which is an integral part of the global climate system. The melting cryosphere is a major factor in sea-level rise, which has enormous significance to coastal populations throughout the world. During the 2010 Arctic campaign, scientists discovered warm waters in a glacier fjord in East Greenland, and studies revealed that the waters are replenished by wind-driven circulation. Furthermore, in West Greenland measurements of ocean currents, temperature, and salinity suggest that submarine melt rates (the melting of ice below the waterline) are twice as high.

Both discoveries lend support to the idea that ocean warming may, along with calving, be the most important factors in mass loss from the world's major ice sheets. Sea ice reached its minimum extent in 2010 on September 29, when coverage dropped to 1.78 million square miles, according to scientists at the National Snow and Ice Data Center. The extent was lower than the 2009 minimum but remained above the record minimums reached in 2007 and 2008. 2010 saw continued loss of ice from the Greenland and Arctic sea ice cover (especially from the oldest, thickest ice), as well as from the West Antarctic ice sheets.

NASA satellites, such as Aqua, and airborne surveys continue to provide important records of these changes. They also improve understanding of the relationship between ice cover and the oceans and atmosphere, critical for creating predictive models and for developing accurate global climate models.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Develop missions in support of this Outcome, as demonstrated by completing Aquarius Operational Readiness Review (ORR). | None | 8ES10 Yellow | 9ES4 Green | 10ES02 Yellow |
| Conduct flight programs in support of this Outcome, as demonstrated by achieving mission success criteria for Aura. | None | None | None | 10ES03 Green |
| Demonstrate progress in understanding the role of oceans, atmosphere, and ice in the climate system and in improving predictive capability for its future evolution. Progress will be evaluated by external expert review. | 7ESS7 Green | 9ES07 Green | 9ES15 Green | 10ES11 Green |
| Develop missions in support of this Outcome, as demonstrated by completing the Pre-Ship Comprehensive Performance Test for Glory. | 7ESS8 Yellow | 8ES09 Yellow | 9ES3 Red | 10ES21 Yellow |
| Develop missions in support of this Outcome, as demonstrated by conducting the acquisition strategy meeting for the OCO-2 mission, defining the implementation and acquisition approach for the reconstituted mission. | 7ESS6 Yellow | 8ES04 Yellow | 9ES2 Green | 10ES22 Green |
| Develop missions in support of this Outcome, as demonstrated by completing the ICESat-II Initial Confirmation Review. | None | None | 9ES16 Yellow | 10ES12 Green |

**Why NASA did not achieve APG 10ES02:** Due to delays in the development of the international partner's Mission Operations System, the ORR was not completed in FY 2010.

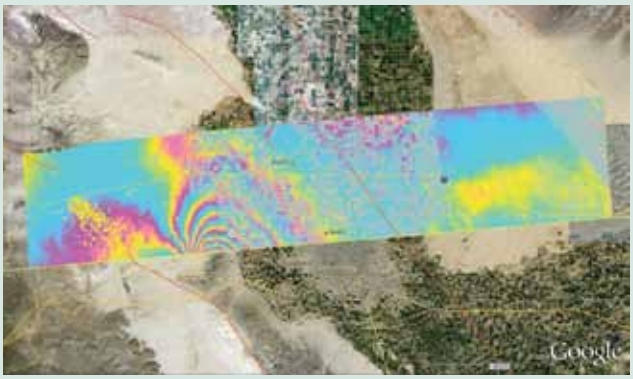
**Plans for achieving 10ES02:** A specific date has not been identified, but NASA estimates this to be in early 2011. However, any delays to the overall mission schedule could cause the ORR to move further.

**Why NASA did not achieve APG 10ES21:** The Glory Pre-Ship Comprehensive Performance Test began on September 17, 2010, but was not completed until October 4, 2010. The test was delayed primarily due to resolution of spacecraft hardware anomalies.

**Plans for achieving 10ES21:** The test was completed successfully on October 4, 2010.

## *Outcome 3A.6: Progress in characterizing and understanding Earth surface changes and variability of Earth's gravitational and magnetic fields.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |




Credit: NASA/JPL/USGS/Google

The image shows a UAVSAR interferogram of the magnitude 7.2 Baja California earthquake on April 4, 2010, overlaid atop a Google Earth image of the region. Major fault systems are shown by red lines, while recent aftershocks are denoted by yellow, orange, and red dots. For more about this and other radar images, go to: *http://www.nasa.gov/topics/earth/features/UAVSAR20100623.html*.

**Missions new and old prove their benefit**

NASA's projects for characterizing gravitational fields and Earth's surface changes have been very successful. The capabilities resulting from these projects have proven useful in forecasting seismic events on a variety of time scales. In FY 2010, NASA has continued to invest in these capabilities for the public benefit.

NASA has invested in the development of real-time Global Differential Global Positioning System (GDGPS) network, both for the prediction of hazards like earthquakes and tsunamis and for navigation. GDGPS demonstrated its value by predicting and observing the tsunami generated by the Chilean earthquake of February 27, 2010. The subsequent observation of the tsunami by the Jason-I and -II Earth observation satellites confirmed that the amplitudes predicted by the system's model were remarkably accurate.

This past year was the first full year of operations for NASA's unmanned airborne observation platform, and it was a highly successful year. The Uninhabited Aerial Vehicle Synthetic Aperture Radar, or UAVSAR, captured the first-ever airborne InSAR (Interferometric Synthetic Aperture Radar) measurement of ground deformation due to an earthquake (the northern extent of the magnitude 7 earthquake in Baja California). NASA-funded investigators also led the effort in the use of satellite InSAR observations to respond to the large earthquakes in Baja California, Haiti, and Chile.

The Gravity Recovery and Climate Experiment (GRACE) twin spacecraft continued to provide monthly measurements of Earth's gravity field, helping scientists to make major advances in observing and understanding the mass flux associated with the regional changes in gravity. Specific phenomena observed by GRACE include mass loss in the polar ice caps, flooding events in major river basins, decadal signals associated with ground water depletion, and ocean bottom pressure changes leading to changes in the ocean bottom currents. In June 2010, NASA and the German Aerospace Center (DLR) signed an agreement to extend the mission through the end of its on-orbit life, which is expected in 2015. GRACE's monthly maps are up to 100 times more accurate than existing maps, substantially improving the accuracy of techniques used by oceanographers, hydrologists, glaciologists, geologists, and climate scientists.

More information on the NASA Global Differential GPS System is available at *http://www.gdgps.net/*.

More information on the UAVSAR is available at *http://uavsar.jpl.nasa.gov/*.

More information on GRACE can be found at *http://www.csr.utexas.edu/grace/*.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Develop missions in support of this Outcome, as demonstrated by completing the Landsat Data Continuity Mission (LDCM) Confirmation Review. | None | None | 9ES11 Yellow | 10ES08 Green |
| Demonstrate progress in characterizing and understanding Earth surface changes and variability of Earth's gravitational and magnetic fields. Progress will be evaluated by external expert review. | 7ESS10 Green | 8ES11 Green | 9ES17 Green | 10ES13 Green |

## *Outcome 3A.7: Progress in expanding and accelerating the realization of societal benefits from Earth system science.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |

**NASA Earth Science data serves the public, at home and abroad**

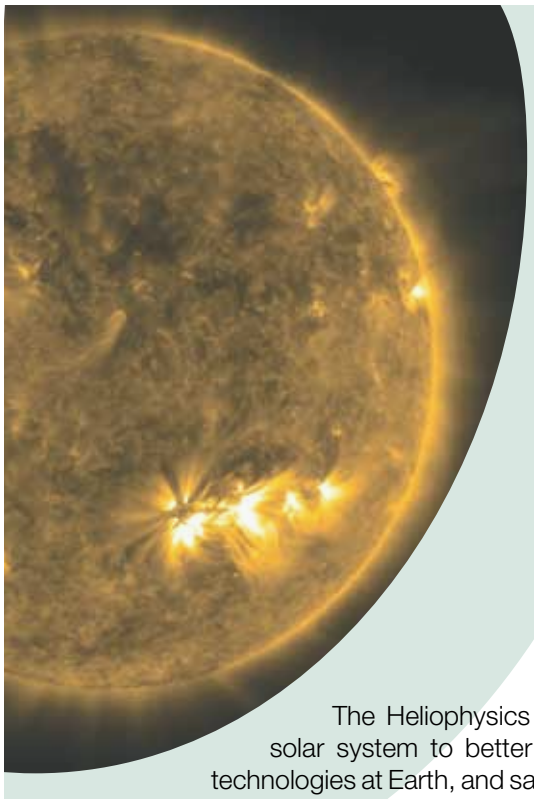
Throughout FY10, NASA and the U.S. Agency for International Development (USAID) worked to establish the new SERVIR–Himalaya node in Kathmandu, Nepal, which was formally inaugurated on October 5, 2010. SERVIR–Himalaya is the third global node in the SERVIR Regional Visualization and Monitoring System, and is hosted by the International Centre for Integrated Mountain Development. It expands the collaboration between NASA, USAID, and their international partners to meet development challenges by "linking space to village." Approximately 1.3 billion people depend on the ecosystem services, e.g., abundant fresh water, provided by the Himalayan mountains, yet the region is known as Earth's "third pole" because of its inaccessibility and the vast amount of water stored there in the form of ice and snow SERVIR integrates Earth science data from NASA satellites with geospatial information products from other government agencies to support and expand the International Centre for Integrated Mountain Development's focus on critical regional issues such as disaster management, biodiversity conservation, trans-boundary air pollution, snow and glacier monitoring, mountain ecosystem management, and climate change adaptation. Since 2005, SERVIR has served the Mesoamerican region and the Dominican Republic from the Water Center for the Humid Tropics of Latin America and the Caribbean, which is based in Panama. SERVIR also has served East Africa since 2008, operating from the Regional Center for Mapping of Resources for Development in Nairobi, Kenya.

For more on SERVIR go to *http://www.nasa.gov/mission_pages/servir/10-154.html*.

The Natural Disasters program coordinated NASA's response to several international and national disasters in 2010. Following the Haiti Earthquake in January 2010, NASA spaceborne and airborne instruments observed and monitored the island. Pre-earthquake satellite imagery compared with post-earthquake imagery enabled the detection of landslides and potential areas of unstable soils susceptible to erosion and mudslides.

After the explosion and collapse of the Deepwater Horizon oil platform on April 20, 2010, NASA contributed its satellite and aircraft research capabilities in support of the broader national effort to respond to the oil spill in the Gulf of Mexico. This effort continued throughout the summer and into October. NASA supplied data from six different instruments on four research spacecraft, as well as five instruments deployed on dedicated aircraft missions. From their vantage point in low Earth orbit, the Moderate-resolution Imaging Spectroadiometer (MODIS) instrument observed a 2,300 kilometer wide swath of ocean surface and resolved details down to about 250 meters. These remote sensing assets collected data on the spill four times every 24 hours and provided large-scale visible and infrared views of the slick. Data from higher resolution instruments (Advanced Spaceborne Thermal Reflection Radiometer and the Advanced Land Imager) can show details as small as 10 meters across, but for a much narrower swath of ocean. NASA aircraft missions over the spill supplemented the satellite data with higher resolution imaging. The U.S. Geological Survey (USGS) and NOAA used these NASA measurements as a key component in estimating the volume and concentration of surface oil in the Gulf of Mexico.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Issue 12 reports with partnering organizations that validate using NASA research capabilities (e.g., observations and/or forecast products) could improve their operational decision support systems. | 7ESS11 Green | 8ES12 Green | 9ES18 Green | 10ES14 Green |
| Increase the number of distinct users of NASA data and services. | None | 8ES13 Green | 9ES19 Green | 10ES15 Green |
| Maintain a high level of customer satisfaction, as measured by exceeding the most recently available federal government average rating of the Customer Satisfaction Index. | None | 8ES14 Green | 9ES20 Green | 10ES16 Green |



# Sub-Goal 3B

## Understand the Sun and its effects on Earth and the solar system.

| Summary of Ratings for Sub-Goal 3B | |
|---|---|
| 3 Outcomes | 8 APGs |
| Green = 3 | Green = 8 |
| Yellow = 0 | Yellow = 0 |
| Red = 0 | Red = 0 |
| White = 0 | White = 0 |

| FY 2010 Cost of Performance (Dollars in Millions) |
|---|
| $1,019.9 |

The Heliophysics Division explores the Sun's connection with, and effects on, the solar system to better understand the interaction between the Earth and Sun, protect technologies at Earth, and safeguard space exploration. NASA Heliophysics missions are making historical strides toward understanding and predicting space weather and the space environment.

The Sun's energy output creates an immense structure of complex magnetic fields and winds, known as the heliosphere, which stretches far beyond the orbit of Pluto. Using a group of robotic science spacecraft to form an extended network of sensors, NASA observes solar variability and the response of Earth and other planets to such variability. Over a dozen satellites comprise the Heliophysics System Observatory to provide unprecedented wide-ranging coverage of the vast Sun–Earth system. The satellites provide key links to understanding the complex interactions between the Sun and the solar system, including the first detailed measurements of the Sun's meridional flow, the conveyor belt-like magnetic field running from the Sun's equator to its poles. Also observed for the first time is the ground state of Earth's atmosphere and ionosphere. At the same time, advances in computational capabilities and hardware yielded complex predictive models with ever-increasing realism and closure with data.

This timely convergence of discovery and assets has enabled the Heliophysics Division to make great strides toward understanding and predicting space weather, the space environment, and how Earth will respond to the Sun's activity.

## Benefits

Due to an increased reliance on space-based technologies, the modern world is now more vulnerable and sensitive to space weather and solar activity. A report issued in December 2008 by the Space Studies Board of the U.S. National Academies addressed the impacts of space weather events on human technologies. The report, *Severe Space Weather Events: Understanding Societal and Economic Impacts* (available at *http://www.nap.edu/catalog.php?record_id=12507*), estimates that the economic cost of a severe geomagnetic storm could cost the United States up to $2 trillion during the first year, with long recovery times resulting from damage to large power transformers and other necessary but hard-to-replace facilities.

Image above: The Solar Dynamics Observatory (SDO) watched in extreme ultraviolet light as a fairly strong active region rotated across the center of the Sun over the course of four and a half days (July 23–27, 2010). The looping arcs above this active region were in ever changing motion the entire time. (Credit: NASA/SDO Team)

NASA partners with NOAA to operate a fleet of scientific satellites to observe space weather. NASA spacecraft, equipped with space weather beacons, provide real-time science data to space weather forecasters. NASA cooperates with other agencies to enable new knowledge in this area and to measure conditions in space critical to both operational and scientific research.

Equally important, Earth's local space environment provides a convenient venue for studying the plasmas that make up most of the visible universe. Under the control of magnetic fields, plasmas organize into galactic jets, radio filaments, supernova bubbles, accretion disks, galactic winds, stellar winds, stellar coronas, sunspots, heliospheres, magnetospheres, and radiation belts. Studying these phenomena in Earth's own neighborhood gives NASA the opportunity to understand the underlying mechanics of distant astrophysical plasma systems that are inaccessible to direct study.

## Risks to Achieving Sub-Goal 3B

The Heliophysics Division, along with NASA's other Science divisions, continues to be concerned with the increased cost and the reduced availability of expendable launch vehicle (ELV) options. Over the course of the last decade, the Delta II has been the workhorse for launching many robotic mid-sized spacecraft. Without this option, NASA has access only to costlier evolved ELVs (Delta IV, Atlas V), which were designed to launch payloads larger than planned for many of the Heliophysics missions identified in the NASA Science Plan. Possible cost growth in the evolved ELV class is an additional source of concern. These problems cannot be avoided until new commercial launch vehicles become available, potentially reducing the cost of launching missions.

Rising mission costs also present a risk, as the reduced mission frequency impacts the systems approach to Heliophysics. NASA is aggressively exploring options to maintain a vital Heliophysics flight program. With the release of the Explorer Announcement of Opportunity (AO) on November 1, 2010, the program is taking a vital step toward maintaining an appropriate mix of small and large missions.

## *Outcome 3B.1: Progress in understanding the fundamental physical processes of the space environment from the Sun to Earth, to other planets, and beyond to the interstellar medium.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |

Credit: UCAR

When Earth's thermosphere contracts, and the upper regions at the edge of space become less dense, objects in orbit experience less drag. This means that orbital debris, including satellites that have ceased operations, will spend a longer time in orbit, where they can be a hazard to spacecraft in operations.

**NASA Heliophysics passes major milestones contributing to Outcome 3B.1**

The Solar Dynamics Observatory (SDO) launched February 11, 2010—The observatory is returning images that demonstrate an unprecedented capability for scientists to understand the Sun's dynamic processes.

Magnetospheric Multiscale (MMS) completed its critical design review (CDR) and is finishing final design prior to the start of integration and testing.

NASA completed instrument selections for the Solar Probe Plus mission.

Go to *Missions At a Glance* for more information on these missions.

**The Sun and humankind conspire to contract the thermosphere**

NASA-funded researchers are monitoring a big event in Earth's atmosphere. High above the surface where the atmosphere meets space, a rarefied layer of gas called the thermosphere recently collapsed and now is rebounding again.

The collapse happened during the deep solar minimum of 2008-2009, a fact that comes as little surprise to researchers. The thermosphere always cools and contracts when solar activity is low. In this case, however, the magnitude of the collapse was two to three times greater than could be explained by low solar activity. This was discovered by NASA's Coupled Ion-Neutral Dynamics Investigation (CINDI) instrument, aboard the Air Force Communication/Navigation Outage Forecast System (C/NOFS) satellite. The C/NOFS space weather mission was designed to explore disturbances in Earth's ionosphere that can cause disruption of navigation and communication signals.

The thermosphere is where solar radiation makes first contact with Earth. It intercepts extreme ultraviolet (EUV) photons from the Sun before they can reach the ground. When solar activity is high, solar EUV warms the thermosphere, causing it to expand. When solar activity is low, it contracts. The extra contraction may have been caused by carbon dioxide. When carbon dioxide, produced by human-related activities near the surface, gets into the thermosphere, it acts as a coolant, shedding heat via infrared radiation. As the thermosphere rebounds, CINDI and other spacecraft can collect important clues about how trends in global climate could alter the composition of the thermosphere, changing its thermal properties and the way it responds to external stimuli.

For more on this story, visit *http://science.nasa.gov/science-news/science-at-nasa/2010/15jul_thermosphere/*.

**Identifying the particle acceleration region of a solar flare**

Solar flares are among the most energetic phenomena in the solar system, releasing vast amounts of energy in a few minutes, both heating the local solar atmosphere to millions of degrees and accelerating particles to relativistic speeds. Scientists think the release of magnetic energy is the source of energy for the flares, but they did not know the details of the particle acceleration mechanism. Even the location of the acceleration site was under debate, although it was generally assumed to be in the corona, the glowing plasma "atmosphere" that surrounds the Sun. NASA's Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) mission and the Nobeyama

Radioheliograph may have solved at least part of this mystery.

Recent observations have demonstrated the presence of high-energy electrons high in the solar corona, in an area called "above-the-loop-top" because it is above the region where the post-solar flare magnetic loops form. The observations establish that the electron population was produced by a mechanism that accelerates all the available electrons, indicating in turn that the above-the-loop-top source is the acceleration region itself.

Additional studies are planned, in particular with Hinode and the Solar Dynamics Observatory, to verify these findings. The study of particle acceleration sources in the solar corona is crucial in gaining an understanding of how solar flares occur and evolve and how the vast amounts of energy released by stars like the Sun travel through interplanetary space and affect planetary environments.


Credit: NASA/SDO/AIA

Earth is superimposed next to an image of a coronal loop taken by the Solar Dynamics Observatory in March 2010 to give a sense of scale. These highly structured and elegant loops are a direct consequence of the twisted solar magnetic flux within the solar body. They are often found with sunspots at their footpoints. The upwelling magnetic flux pushes through the photosphere, the core of the Sun that appears to emit its light, exposing the cooler plasma below.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Demonstrate progress in understanding the fundamental physical processes of the space environment from the Sun to Earth, to other planets, and beyond to the interstellar medium. Progress will be evaluated by external expert review. | 7ESS13 Green | 8HE01 Green | 9HE1 Green | 10HE01 Green |
| Develop missions in support of this Outcome, as demonstrated by completing the Magnetospheric Multiscale (MMS) spacecraft Critical Design Review (CDR). | 7ESS15 Red | 8HE02 Green | 9HE2 Green | 10HE02 Green |
| Develop missions in support of this Outcome, as demonstrated by completing the Geospace Radiation Belt Storm Probes Critical Design Review (CDR). | 7ESS16 Green | 8HE04 Green | 9HE3 Green | 10HE03 Green |
| Develop missions in support of this Outcome, as demonstrated by the award of Solar Probe Plus instrument contracts. | None | None | None | 10HE04 Green |
| Conduct the flight program in support of this Outcome, as demonstrated by achieving mission success criteria for Hinode (Solar-B), THEMIS, and IBEX. | None | None | 9HE5 Green | 10HE05 Green |

## *Outcome 3B.2: Progress in understanding how human society, technological systems, and the habitability of planets are affected by solar variability and planetary magnetic fields.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |

Credit: NASA

Astronauts aboard the ISS photographed these blue noctilucent clouds in July 2008. Noctilucent clouds form on the edge of space, 50 miles above Earth, throughout the polar summer. A dramatic new AIM finding reveal that Earth's lower and upper atmospheres constitute a globally coupled system: Noctilucent clouds in one hemisphere's mesosphere occasionally respond directly to wind speeds in the opposite hemisphere's stratosphere, more than 12,400 miles away. This global scale coupling takes place through wave interactions that have become the focus of intense study.

**NASA Heliophysics passes major milestones contributing to Outcome 3B.2**

Radiation Belt Storm Probes (RBSP) mission has completed its critical design review (CDR) and has been approved to proceed into implementation activities.

Go to *Missions At a Glance* for more information on this mission.

**Ice clouds near the edge of space**

The genesis of beautiful, wispy noctilucent (night-shining) clouds has been an ongoing mystery. First noticed in the late 19th century, people had to go to places like Scandinavia, Siberia, and Scotland to see them. In recent years, however, they have been sighted from mid-latitudes like Colorado and Utah. Researchers began to wonder if their origin and migration is connected with climate change. NASA's Aeronomy of Ice in the Mesosphere (AIM) mission has provided major advances in understanding the relationship between noctilucent clouds and the environment in which they form.

AIM has revealed the sudden response of cloud formation to temperature excursions below the frost point, much like the turning on of a geophysical light bulb. Cloud brightness and occurrence respond dramatically to even very small changes in the surrounding temperature. Moreover, AIM has confirmed that it is the change in temperature, as opposed to a change in the abundance of the background water vapor that controls the seasonal onset of cloud formation. However, water vapor does appear to play an important role in governing the subsequent behavior of the clouds, because its availability limits the amount of ice that can be formed.

The AIM scientists also have been able to show that when they know the mesospheric temperature and water vapor abundances, they can model a number of important features of the clouds, and from this develop a predictive capability. NASA has extended AIM's mission, which began with its 2007 launch, to 2012. The science team believes that with additional data they can find out why the clouds first appeared in the late 1800s, why they are spreading, and if they are connected to human activity or some other process.

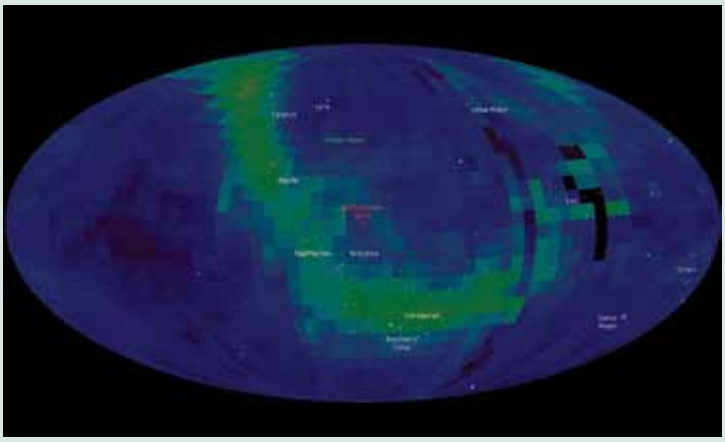
For more on this story go to *http://science.nasa.gov/science-news/science-at-nasa/2008/25aug_nlc/*.

**Mapping the solar system's protective "bubble"**

NASA's Interstellar Boundary Explorer (IBEX) has provided the first global views of the protective boundary, called the heliosphere, that surrounds the solar system and shields it from the harmful radiation in the galactic medium. The data reveal that conditions at the edge of the solar system may be much more dynamic than previously thought.

The maps are made by collecting particles known as energetic neutral atoms (ENAs), which are created by the collisions of solar wind particles with the in-flowing interstellar gas. The maps show a remarkably bright and narrow "ribbon" of ENAs not predicted by any model or theory. The observations indicate a blunt termination shock (a bubble-shaped area where the solar wind is slowed by pressure from gas outside the solar system) that is wide in longitude and flattened latitudinally. Scientists are still debating the origin of this ribbon, but it appears to show the imprint of the galactic magnetic field, which shapes and controls the global heliosphere.

Meanwhile, the two Voyager missions continue making direct samples of the most distant plasmas ever measured. For example, scientists expected the supersonic solar wind to be abruptly slowed when encountering the solar system's interface with the intergalactic wind, forming a termination shock. However, Voyager 2 has discovered that ions in the solar wind bounce back and forth across the shock formation, slowly gaining speed as they drain energy from the supersonic wind. So many ions were extracting energy from the solar wind, in fact, that the solar wind had slowed by 20 percent before the final shock boundary, resulting in a weaker shock than expected.



Credit: IBEX Team/Goddard Scientific Visualization Studio/ESA

The ribbon observed by IBEX is a narrow bright feature that spans much of the nighttime sky linking together the summer constellation of Cygnus, the swan, Aquila, the eagle, the center of the Milky Way galaxy, Ursa Major and Ursa Minor.

These results show that the interaction between the solar system and the interstellar medium has remarkable structure and dynamics. The results have already changed scientists' understanding about the solar system's home in the galaxy, how galactic cosmic rays reach Earth, and how the environments surrounding other stars may or may not influence the possibility of the existence of habitable planets in other solar systems.

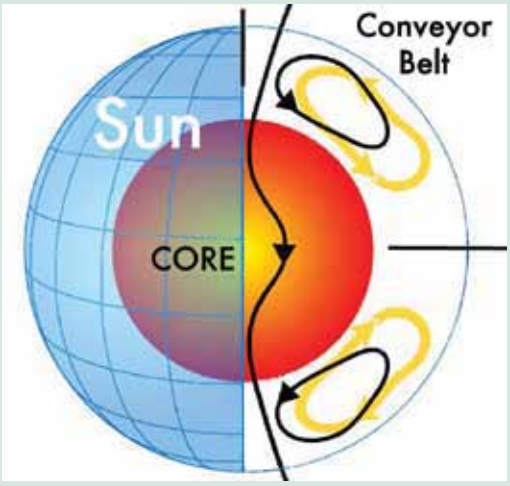
For more on IBEX's story, visit *http://science.nasa.gov/science-news/science-at-nasa/2009/15oct_ibex/*.

For more on the Voyagers' interstellar mission go to *http://voyager.jpl.nasa.gov/*.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Develop missions in support of this Outcome, as demonstrated by completing the Magnetospheric Multiscale (MMS) spacecraft Critical Design Review (CDR). | 7ESS15 Red | 8HE02 Green | 9HE2 Green | 10HE02 Green |
| Develop missions in support of this Outcome, as demonstrated by completing the Geospace Radiation Belt Storm Probes Critical Design Review (CDR). | 7ESS16 Green | 8HE04 Green | 9HE3 Green | 10HE03 Green |
| Develop missions in support of this Outcome, as demonstrated by the award of Solar Probe Plus instrument contracts. | None | None | None | 10HE04 Green |
| Demonstrate progress in understanding how human society, technological systems, and the habitability of planets are affected by solar variability and planetary magnetic fields. Progress will be evaluated by external expert review. | 7ESS19 Green | 8HE03 Green | 9HE6 Green | 10HE06 Green |
| Conduct the flight program in support of this Outcome, as demonstrated by achieving mission success criteria for THEMIS. | None | None | 9HE7 Green | 10HE07 Green |

## *Outcome 3B.3: Progress in developing the capability to predict the extreme and dynamic conditions in space in order to maximize the safety and productivity of human and robotic explorers.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |




Credit: NASA

The meridial flow is like a conveyor belt—a massive circulating current of fire (hot plasma) within the Sun. It has two branches, north and south, each taking about 40 years to complete one circuit. Researchers believe the turning of the belt controls the sunspot cycle. The top of the belt skims the surface of the Sun, sweeping up magnetic elements and carrying them toward the poles. SOHO is able to track those magnetic elements, revealing the speed of the underlying flow.

**NASA Heliophysics passes major milestone contributing to Outcome 3B.3**

SDO launched February 11, 2010—The first Living with a Star (LWS) mission and the newest component of the Heliosphysics Great Observatory, SDO has a downlink data rate of 1.5 Terabytes per day, which allows high time cadence, full disk images of the Sun to be obtained in multiple wavelength bands at a maximum rate of eight to 10 images every 10 seconds.

Go to *Missions At a Glance* for more information on this mission.

**Understanding an unusually long solar cycle**

In the outer third of the Sun, energy is transported by convective motions akin to those of water boiling in a pot. Scientists believe the approximate 11-year solar activity cycle is driven by compact elements of magnetic field moving through what is called the "convection zone." New results by researchers using data from the Solar and Heliospheric Observatory (SOHO) have found a distinctive signature that may explain why the current solar cycle has been so long.

The researchers used a method that examines variations in the meridional flow (a poleward surface wind) of strong magnetic field elements in the Sun's photosphere, or the ball-shaped surface that is perceived to emit light. SOHO took measurements of the flow pattern from 1996 to 2010, and the subsequent research shows that one component of the surface flow velocity has remained at a nearly constant and high value throughout the recent extended (2008 through 2009) solar minimum. These findings contradicted models that said a fast-moving flow should speed up sunspot production. The models suggest that the flow sweeps up magnetic fields from the Sun's surface and drags them down to the inner dynamo. There the fields are amplified to form the underpinnings of new sunspots. A fast-moving flow should accelerate this process.

The reasons that sunspots are not forming may be found at the Sun's poles, where data showed magnetic field strength to be low. At the same point in the cycle for the previous solar minimum in 1996 the surface velocity of the meridional flow would have already started to decrease in magnitude. The fact that the surface flow speed is still high supports models that predict that faster surface flow speeds lead to weaker polar magnetic fields and, hence, a longer solar minimum.

For more on this story, visit *http://science.nasa.gov/science-news/science-at-nasa/2010/12mar_conveyorbelt/*.

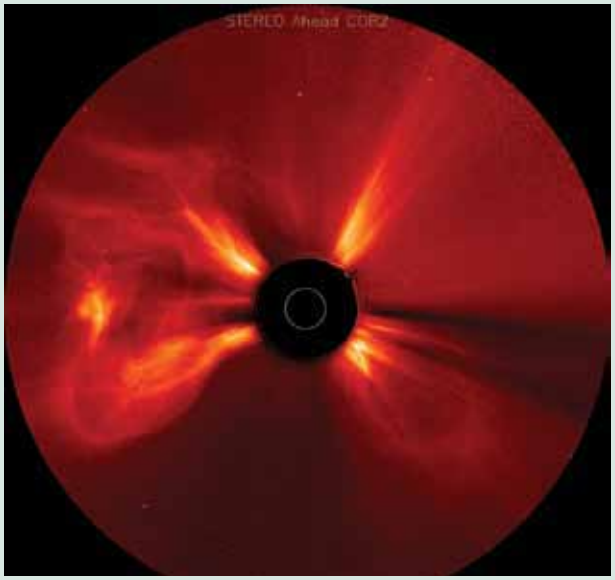
**Advances in predicting solar eruptions**

Coronal mass ejections (CMEs) are huge bubbles of gas threaded with magnetic field lines that are ejected from the Sun over the course of several hours. CMEs disrupt the flow of the solar wind and produce disturbances that strike Earth with sometimes catastrophic results. Observations from widely-separated spacecraft, like NASA's two Solar Terrestrial Relations Observatory (STEREO) spacecraft, have spurred progress in the development of more realistic and more reliable numerical models of interplanetary CMEs and solar energetic particle (SEP) events.

Tracking CMEs and SEPs continuously from the Sun to Earth is crucial for developing practical capability in space weather forecasting, which has important consequences for life and technology on the Earth and in space.

The developments that ultimately will contribute to predictive space-weather capabilities include: using STEREO's stereoscopic viewing capability to derive the direction and speed of CMEs, thereby improving prediction of arrival times at Earth, where they can initiate geomagnetic storms; using observations from NASA's Wind spacecraft and STEREO to model how solar-wind streams govern evolution of magnetic topology during transit from the Sun; modeling large-scale CME-driven shocks to predict how SEP time-intensity profiles vary with source location and reflect structure in solar-wind streams; and improving modeling of SEP access to Earth's atmosphere and effects on space systems.

For more on STEREO go to *http://www.nasa.gov/mission_pages/stereo/main/index.html*.




Credit: NASA

A coronagraph on the STEREO A (Ahead) spacecraft caught at least two photogenic CMEs over two days, August 7 and 8, 2010. Although it appeared that this blast was Earth-directed, observations by other spacecraft showed that most of it was not headed toward Earth.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Develop missions in support of this Outcome, as demonstrated by completing the Geospace Radiation Belt Storm Probes Critical Design Review (CDR). | 7ESS16 Green | 8HE04 Green | 9HE3 Green | 10HE03 Green |
| Demonstrate progress in developing the capability to predict the extreme and dynamic conditions in space in order to maximize the safety and productivity of human and robotic explorers. Progress will be evaluated by external expert review. | 7ESS20 Green | 8HE05 Green | 9HE8 Green | 10HE08 Green |

# Sub-Goal 3C

## Advance scientific knowledge of the origin and history of the solar system, the potential for life elsewhere, and the hazards and resources present as humans explore space.

| Summary of Ratings for Sub-Goal 3C | |
|---|---|
| 4 Outcomes | 11 APGs |
| Green = 4 | Green = 8 |
| Yellow = 0 | Yellow = 3 |
| Red = 0 | Red = 0 |
| White = 0 | White = 0 |

| FY 2010 Cost of Performance (Dollars in Millions) |
|---|
| $2,032.9 |

Since humankind's first exploratory steps into the solar system, NASA has broadened its reach with an increasingly sophisticated series of explorers that have landed on asteroids, tasted the swirling gases of Jupiter's atmosphere, and collected the breath of the Sun.

In support of this Sub-goal, the Planetary Science Theme uses robotic science missions to investigate alien and extreme environments throughout the solar system. These missions help scientists understand how the planets of the solar system formed, what triggered the evolutionary paths that formed rocky terrestrial planets, gas giants, and small, icy bodies, and the origin, evolution, and habitability of terrestrial bodies. The data from these missions guide scientists in the search for life and its precursors beyond Earth and provide information to help NASA plan future human missions into the solar system.

## Benefits

NASA's robotic science missions are paving the way for understanding the origin and evolution of the solar system and identifying past and present habitable locations. With this knowledge, NASA is potentially enabling human space exploration by studying and characterizing alien environments and identifying possible resources that will enable safe and effective human missions to the Moon and beyond.

Robotic explorers gather data to help scientists understand how the planets formed, what triggered different evolutionary paths among planets, and how Earth formed, evolved, and became habitable.

To search for evidence of life beyond Earth, scientists use this data to map zones of habitability, study the chemistry of alien worlds, and unveil the processes that lead to conditions necessary for life.

Image above: The surface of Saturn's moon Dione is rendered in crisp detail against a hazy, ghostly Titan. A portion of the "wispy" terrain of Dione's trailing hemisphere can be seen on the right. Also visible in this image are hints of atmospheric banding around Titan's north pole. (Credit: NASA/JPL/Space Science Institute)

Through the Near Earth Object Observation Program, NASA identifies and categorizes asteroids and comets that come close to Earth. Every day, a hundred tons of interplanetary particles drift down to Earth's surface, mostly in the form of dust particles. Approximately every 100 years, rocky or iron asteroids larger than 164 feet in diameter impact Earth, causing damage like craters and tidal waves, and about every few hundred thousand years, an asteroid larger than a kilometer threatens Earth. In the extremely unlikely event that such a large object threatens to collide with Earth, NASA's goal is to provide an early identification of these hazardous objects as far in advance (perhaps years) as possible.

## Risks to Achieving Sub-Goal 3C

The supply of Plutonium-238 (Pu-238) remains a limiting factor in the exploration of the solar system. NASA has already rescoped New Frontiers-3 due to the limited supply of the Pu-238. NASA requires Pu-238 to make power for missions that travel too far from the Sun for solar power generation. Russia has suspended implementation of its contract with the Department of Energy (DOE) for purchase of Russia's remaining supplies of Pu-238. NASA continues to explore its options with the DOE, but will require appropriation of funds for FY 2011 and FY 2012 to keep the supply of Pu-238, and with it the Planetary Science Program, on track.

## *Outcome 3C.1: Progress in learning how the Sun's family of planets and minor bodies originated and evolved.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |

### Looking back at Mars' watery history

As scientists explore Mars from orbiting spacecraft, landers, and rovers, they have accumulated data showing that Mars was once a wetter planet. Recent observations by NASA and its partners are filling in the history from that wetter past to the present cold, desert climate.

Data from NASA's two Mars Exploration Rovers and the orbiters Mars Odyssey and Mars Reconnaissance Orbiter (MRO), along with the European Space Agency's Mars Express orbiter, show that the planet had a relatively wet environment in which rocks weathered to clay-like minerals, and that as the climate evolved, the planet passed through a stage during which water on or near its surface was more ephemeral and very acidic. They also revealed that this early period produced diverse mineralogy deposits that may be evidence for ancient lakes, springs, or groundwater with salinity and acidity that changed over time.

Finding such a well-preserved geological record of ancient planetary change makes Mars a prime target for understanding how terrestrial planets like Earth, Mars, Venus, and Mercury evolved early in their histories. Other MRO and Mars Express radar observations provided new indications of the cyclic growth of the polar ice caps. This might be analogous to Earth's ice ages, with the ice caps growing or receding over vast timescales based on patterns of polar sunlight.

More on the story about Mars' wet era can be found at *http://mars.jpl.nasa.gov/news/whatsnew/index.cfm?FuseAction=ShowNews&NewsID=1012*.

Credit: NASA/JPL-Caltech/University of Arizona

Layers of exposed rock in the Gale Crater are a record of major environmental changes on Mars billions of years ago. Taken by MRO, the observation shows that clay minerals, which form under very wet conditions, are concentrated in layers near the bottom of the Gale stack. Above that, sulfate minerals are intermixed with the clays. And at the top is a thick formation of regularly spaced layers bearing no detectable water-related minerals. Gale is the first location where a single series of layers has been found to contain these clues in a clearly defined sequence from older rocks to younger rocks.

### The Moon is a watery place

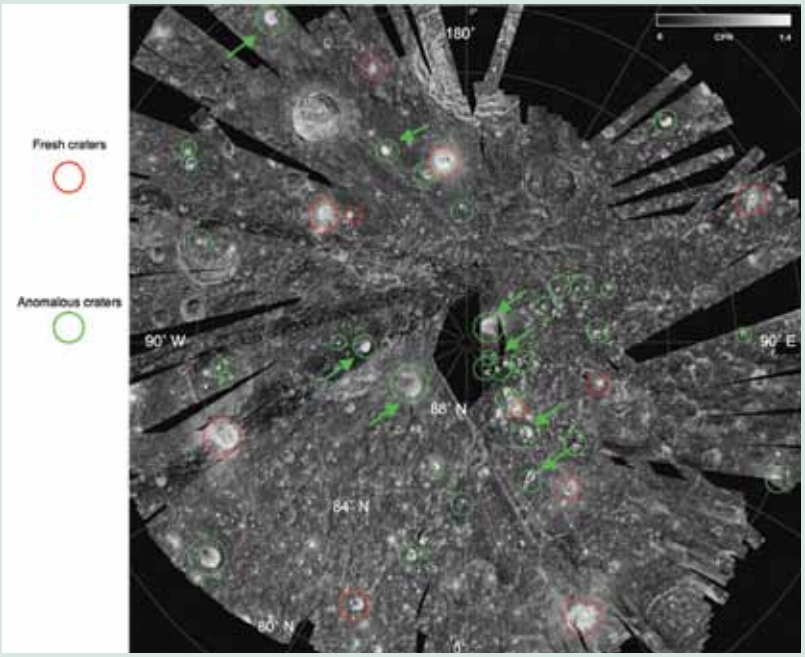
The previous concept of the Moon as a very dry destination recently shifted with the confirmation of the presence of water in FY 2010. Observations from multiple NASA and partner missions have shown that water exists in a variety of concentrations and geologic settings.

Observations by NASA's Moon Mineralogy Mapper (M3) instrument aboard the Indian Chandrayaan-1 spacecraft show hydroxyl and water molecules on the surface of the Moon. These are supported by NASA's Deep Impact spacecraft (on an extended mission called EPOXI), which has shown the entire lunar surface to be hydrated during some portions of the day. The Deep Impact data show the water molecules forming and then dissipating. So far the scientists have found three forms of moon water: the thin, ephemeral layer found by the M3; nearly-pure crater ice found by NASA's Mini-SAR instrument aboard Chandrayaan-1; and a fluffy mix of ice crystals and dirt found by NASA's Lunar Crater Observation and Sensing Satellite (LCROSS), which struck water in October 2009 in a cold, permanently dark crater at the lunar south pole. Scientists postulate that hydrogen ions from the Sun are carried by the solar wind to the Moon, where they interact with oxygen-rich minerals in lunar soil and rock to produce the water and hydroxyl molecules. This water is formed in the morning and then by lunar midday, heat from the Sun causes the molecules to evaporate. The Moon also is constantly bombarded by impactors that add to the lunar water budget. Asteroids contain hydrated minerals, and comet cores are nearly pure ice. Scientists think that much of the crater water migrates to the poles from the Moon's warmer, lower latitudes.

For more on this story, go to *http://science.nasa.gov/science-news/science-at-nasa/2010/18mar_moonwater/*.

A Mini-SAR radar map of the lunar north pole shows identified impact craters. Craters circled in green are believed to contain significant deposits of frozen water. These craters also are in permanent shadow. Scientists estimate that these craters contain over one metric ton of water.

Credit: NASA/Mini-SAR Team, LPI




| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Demonstrate progress in learning how the Sun's family of planets and minor bodies originated and evolved. Progress will be evaluated by external expert review. | 7SSE1 Green | 8PS01 Green | 9PS1 Green | 10PS01 Green |
| Develop missions in support of this Outcome, as demonstrated by completing the Juno Systems Integration Review (SIR). | 7SSE3 White | 8PS03 Green | 9PS2 Green | 10PS02 Green |
| Develop missions in support of this Outcome, as demonstrated by completing the GRAIL Critical Design Review (CDR). | None | None | 9PS3 Green | 10PS03 Green |
| Develop missions in support of this Outcome, as demonstrated by selecting concept studies for the New Frontiers 3 mission. | None | None | None | 10PS04 Green |
| Develop missions in support of this Outcome, as demonstrated by selecting concept studies for the Discovery 12 mission. | None | None | None | 10PS05 Yellow |
| Develop missions in support of this Outcome, as demonstrated by completing the Mars Science Laboratory (MSL) flight hardware builds and flight system assemblies. | 7SSE5 Green | 8PS05 Green | 9PS4 Red | 10PS06 Yellow |

**Why NASA did not achieve APG 10PS05:** The acquisition timeline for the Discovery 12 mission was extended due to the complexity of the Announcement of Opportunity, which includes the potential use of radioisotope power systems.

**Plans for achieving 10PS05:** Twenty-eight proposals have been received. Selection of concept studies is scheduled for mid-FY 2011.

**Why NASA did not achieve APG 10PS06:** The flight hardware build and flight system assembly of the Sample Analysis at Mars (SAM) instrument were not completed during the designated fiscal year, due to complications in the development of the Wide Range Pump (WRP) components of the instrument. The materials originally specified as the primary component of a high-speed, high-performance bearing proved to be inadequate to provide the necessary performance on the surface of Mars, and alternative bearing materials and components had to be researched and developed.

**Plans for achieving 10PS06:** The development of the new bearing designs has been completed and implemented, and the finalization of the flight hardware build has resumed. The final flight units are on schedule to be delivered in early December 2010.

## *Outcome 3C.2: Progress in understanding the processes that determine the history and future of habitability in the solar system, including the origin and evolution of Earth's biosphere and the character and extent of prebiotic chemistry on Mars and other worlds.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |

Credit: NASA/JPL-Caltech/University of Arizona

This view of Mars, taken by MRO, shows color variations in bright layered deposits on a plateau near Juventae Chasma in the Valles Marineris region of Mars. Researchers have found that these bright layered deposits contain opaline silica and iron sulfates, consistent with low-temperature, acidic aqueous alteration of basaltic materials—or acidic water.

**Finding a place for life on Mars**

As described under Outcome 3C.1, the surface of Mars transitioned through a period in its history when the environment was acidic. This sort of hostile environment would challenge both the development of life and the preservation of trace signatures of that life. Research using data from NASA's Mars missions is revealing the nature of the planet's past and what it could mean for the development of life there.

If life once existed on Mars, evidence of that life would have been eradicated by a planet-wide, very acidic period. However, MRO, Mars Odyssey, and the Mars Exploration Rovers observed that these acidic environments only occurred regionally, not globally. For example, data from the rover *Opportunity* showed the existence of two separated and chemically distinct water-based environments in Meridiani Planum: a subsurface environment shielded from the atmosphere with a neutral acidity balance, and a surface environment driven to high acidity by rapid oxidation when iron in minerals was exposed to the atmosphere. Furthermore, MRO and the rover *Spirit* found carbonate deposits, which would have been destroyed by acidic conditions if acidity was globally prevalent. This is important information as Mars missions continue to search for fossil organic chemicals and other signs of past life—geologic features resulting from less acidic environments are the targets of choice.

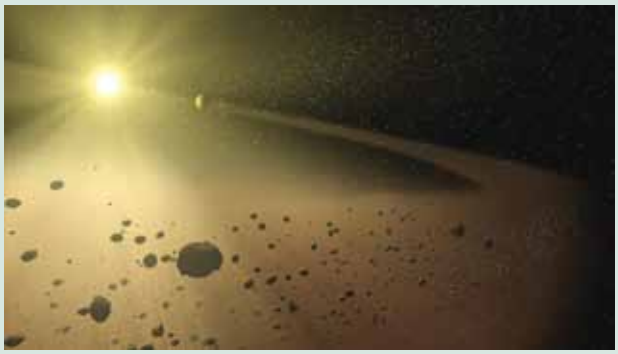
More on *Spirit*'s discovery of a non-acidic wet period on Mars can be found at *http://marsrovers.jpl.nasa.gov/newsroom/pressreleases/20100603a.html*.

**Understanding the evolution of Earth's biosphere**

Usually near-Earth asteroids are portrayed as planet killers, the massive rocks that destroy all plant and animal life. However, NASA research during this fiscal year has shown that despite asteroid bombardments, life on Earth has persisted. In fact, asteroids may have given early Earth some help on its way to being a living planet.

Scientists have suggested that Earth's current supply of water was delivered by asteroids, some time after the collision that produced the Moon (an event that would have vaporized any of the pre-existing water). However, until recently, no measurements of water ice on asteroids had been made. In FY 2010, two research teams, using NASA's Infrared Telescope Facility atop Mauna Kea and the Spitzer Space Telescope, imaged asteroid 24 Themis to show that ice and organic compounds are not only present on its surface, but also widespread. The

same two teams also picked up the telltale signatures of water ice and complex organic solids on the surface of asteroid 65 Cybele. Many scientists thought that these asteroids in this part of the solar system were too close to the Sun to carry water ice. Finding water ice on them now, approximately 4.6 billion years after the solar system was created, suggests that the asteroids may have delivered much of the water and the building blocks for life on Earth.



Credit: NASA/JPL-Caltech

In this artist's concept, a narrow asteroid belt filled with rocks and dusty orbital debris circle a star similar to the Sun. This belt may resemble the one that orbited the inner solar system during its early history.

In FY 2010, scientists also provided clarification about when life could have arisen on Earth and its perseverance through tumultuous events. Based on the geological record, scientists theorize that 3.8 to 4.1 billion years ago Earth went through a period when a number of asteroids and comets came through the inner solar system. Called the Late Heavy Bombardment (LHB), the impacts and near misses would have had a profound effect on the planet's early thermal, climatic, and biological evolution. It is difficult to imagine life existing under such harsh conditions, but NASA-funded researchers, using detailed thermal models of Earth during the epoch, show that under no circumstances was global sterilization on Earth reached during the bombardment. Based on this and other ongoing studies, life's origin on Earth could well have occurred as far back as 4.4 billion years ago. This analysis has shown that if such an early biosphere existed, it would have survived subsequent assaults from the LHB. Life probably arose soon after Earth formed, and has persisted here ever since.

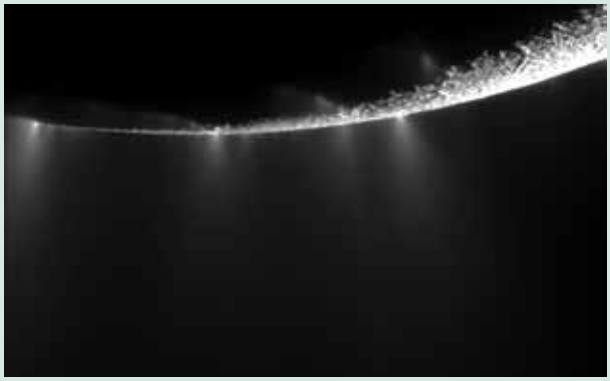
| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Develop missions in support of this Outcome, as demonstrated by completing the Juno Systems Integration Review (SIR). | 7SSE3 White | 8PS03 Green | 9PS2 Green | 10PS02 Green |
| Develop missions in support of this Outcome, as demonstrated by completing the Mars Science Laboratory (MSL) flight hardware builds and flight system assemblies. | 7SSE5 Green | 8PS05 Green | 9PS4 Red | 10PS06 Yellow |
| Demonstrate progress in understanding the processes that determine the history and future of habitability in the solar system, including the origin and evolution of Earth's biosphere and the character and extent of prebiotic chemistry on Mars and other worlds. Progress will be evaluated by external expert review. | 7SSE4 Green | 9PS04 Green | 9PS5 Green | 10PS07 Green |
| Develop missions in support of this Outcome, as demonstrated by completing the Mars Atmosphere and Volatile Evolution Mission (MAVEN) Preliminary Design Review (PDR). | None | None | None | 10PS08 Green |

**Why NASA did not achieve APG 10PS06:** The flight hardware build and flight system assembly of the Sample Analysis at Mars (SAM) instrument were not completed during the designated fiscal year, due to complications in the development of the Wide Range Pump (WRP) components of the instrument. The materials originally specified as the primary component of a high-speed, high-performance bearing proved to be inadequate to provide the necessary performance on the surface of Mars, and alternative bearing materials and components had to be researched and developed.

**Plans for achieving 10PS06:** The development of the new bearing designs has been completed and implemented, and the finalization of the flight hardware build has resumed. The final flight units are on schedule to be delivered in early December 2010.

## *Outcome 3C.3: Progress in identifying and investigating past or present habitable environments on Mars and other worlds, and determining if there is or ever has been life elsewhere in the solar system.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |



Credit: NASA/JPL/Space Science Institute

Dramatic plumes, both large and small, spray water ice out from many locations along the famed "tiger stripes" near the south pole of Saturn's moon Enceladus. The tiger stripes are fissures that spray icy particles, water vapor and organic compounds. This mosaic was created from two high-resolution images taken by NASA's Cassini spacecraft on November 21, 2009.

**Where there is water, there may be life**

From what is known of Earth, where there is water, there is a chance for the existence of life. So for many years scientists have speculated that other worlds with water could support life. In 2010, there were two discoveries that helped scientists characterize the subsurface oceans on Europa, a moon of Jupiter, and Enceladus, a moon of Saturn.

Europa is enveloped by a global ocean about 100 miles deep, with an icy crust that may be only a few miles thick—a thin crust for such a distant, cold moon. The surface of Europa is covered with free oxygen (meaning it is not combined with other elements) and other oxidants that are key to life, but until recently scientists did not believe there was an effective way to deliver the oxygen-rich material to the subsurface ocean. New research shows that tidal forces appear to push fresh ice upward from below in a cycle that forms double ridges on at least half of Europa's surface. As ridges pile on top of ridges, older oxegenated material gets buried, shoving oxygen-rich matter downward toward the liquid water. Scientists have estimated that after one or two billion years this process could deliver enough oxygen-rich material to Europa's ocean to reach the same concentration levels as the oceans on Earth. This oxygen could provide the necessary environment to nurture life.

On Enceladus, plumes of material are ejected from vents on the icy surface, suggesting the presence of a near-surface pocket of water, like cold versions of the Old Faithful geyser in Yellowstone National Park. Previously, scientists were unable to determine if the ocean is still liquid or if it is frozen. Other moons in the solar system usually have liquid-water oceans covered by miles of icy crust, like Europa. Using the Cassini spacecraft's dust detector, scientists discovered evidence of sodium salts in the ice grains comprising Enceladus' plumes. The discovery of these salts is strong evidence that there is a liquid subsurface ocean on Enceladus—maybe only a hundred feet below the surface—because sodium salts would only exist if the plumes originate from liquid water. The next step in the research is to find out if the moon has been active and wet long enough for life to have taken hold in its interior.

More on the plumes and jets on Enceladus can be found at *http://www.nasa.gov/mission_pages/cassini/whycassini/cassini20100223.html* and *http://www.nasa.gov/mission_pages/cassini/media/cassini-20080814.html*.

**Exploring habitable regions on Mars**

NASA planned to launch a new mission, the Mars Science Laboratory (MSL), in 2009 to land on Mars and send out what would be the largest rover to date. Difficulties in the project's development delayed the launch to 2011. But in this cloud has been a silver lining. During this extra time NASA has investigated potential landing sites for MSL—ones that represent a diverse environmental history of environments that may have been (or may still be) habitable.

The Mars Reconnaissance Orbiter (MRO) and Mars Odyssey have provided the data needed to certify the safety and scientific potential of the final four candidate landing sites for MSL, a mission designed to assess whether Mars ever was, or is still today, an environment able to support microbial life. Two of the sites have geology of interest

in ancient paleolakes, the third site has horizontally bedded clay-bearing sedimentary rocks, and the fourth site includes clays formed during a benign environment, which would be more conducive to life, and sulfates formed in a younger, more acidic environment, which likely could not have supported life.

The delay provided an opportunity to acquire the data needed to evaluate two additional landing sites. One site has chloride-bearing sedimentary rocks. Chloride is part of many types of salt, which may have formed over time as large quantities of water evaporated. Furthermore, salt is good for preserving organic material. The other site contains carbonates, which form in wet, near-neutral conditions that could provide a favorable habitat for life. These are far more landing site options than MSL can visit, but Mars' diversity of past aqueous environments provides excellent opportunities for future lander missions searching for life beyond Earth.

More information about MSL is available at *http://marsprogram.jpl.nasa.gov/msl/*.

Credit: NASA/JPL-Caltech

The suspension system on the rover *Curiosity* easily accommodates rolling over a ramp in this September 10, 2010, test drive inside the Spacecraft Assembly Facility at NASA's Jet Propulsion Laboratory. This rover, which dwarfs its predecessors, will be able to roll over larger obstacles and access a wider-variety of terrain.

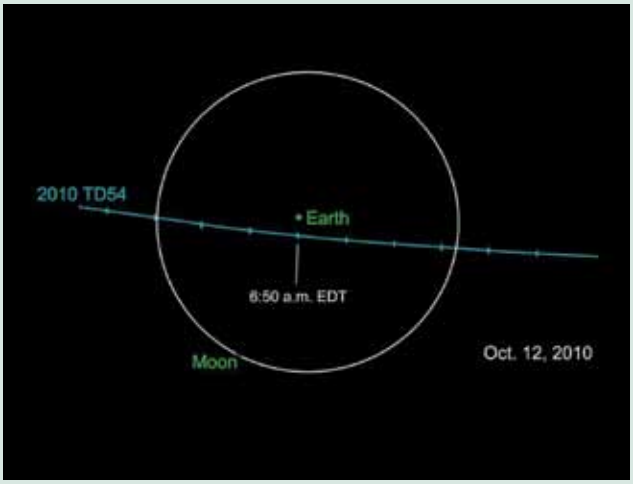
| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Develop missions in support of this Outcome, as demonstrated by completing the Juno Systems Integration Review (SIR). | 7SSE3 White | 8PS03 Green | 9PS2 Green | 10PS02 Green |
| Develop missions in support of this Outcome, as demonstrated by completing the Mars Science Laboratory (MSL) flight hardware builds and flight system assemblies. | 7SSE5 Green | 8PS05 Green | 9PS4 Red | 10PS06 Yellow |
| Develop missions in support of this Outcome, as demonstrated by completing the Mars Atmosphere and Volatile Evolution Mission (MAVEN) Preliminary Design Review (PDR). | None | None | None | 10PS08 Green |
| Demonstrate progress in identifying and investigating past or present habitable environments on Mars and other worlds, and determining if there is or ever has been life elsewhere in the solar system. Progress will be evaluated by external expert review. | 7SSE6 Green | 8PS06 Green | 9PS8 Green | 10PS09 Green |

**Why NASA did not achieve APG 10PS06:** The flight hardware build and flight system assembly of the Sample Analysis at Mars (SAM) instrument were not completed during the designated fiscal year, due to complications in the development of the Wide Range Pump (WRP) components of the instrument. The materials originally specified as the primary component of a high-speed, high-performance bearing proved to be inadequate to provide the necessary performance on the surface of Mars, and alternative bearing materials and components had to be researched and developed.

**Plans for achieving 10PS06:** The development of the new bearing designs has been completed and implemented, and the finalization of the flight hardware build has resumed. The final flight units are on schedule to be delivered in early December 2010.

## *Outcome 3C.4: Progress in exploring the space environment to discover potential hazards to humans and to search for resources that would enable human presence.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |




Credit: NASA/JPL-Caltech

Just after the close of FY 2010 a team at the NASA-sponsored Catalina Sky Survey north of Tucson, Arizona, discovered that a small asteroid about the size of a car was going to fly past Earth on October 12, shown here in a tracking map. Named 2010 TD54, the asteroid passed within 27,960 miles of Earth, measuring from the center of Earth outward. Had it entered Earth's atmosphere, it would have burned up long before reaching the ground.

**Keeping count of near-Earth objects**

Near-Earth objects, asteroids and comets that pass close to or impact with Earth, pose a threat to property, the environment, and even life itself. At the same time, they hold great scientific interest because they represent relatively unchanged debris from the solar system formation process some 4.6 billion years ago. They may carry with them ice and the building blocks of life. NASA funds teams that search for and catalogue near-Earth objects for both planetary protection and scientific purposes.

In FY 2010, asteroid search teams found 19 asteroids larger than one kilometer with orbits coming within Earth's vicinity. The search teams classify the finds as either larger or smaller than one kilometer because asteroids larger than one kilometer would cause global climatic changes. In addition, the teams also found 817 smaller asteroids, bringing the total number of known asteroids to 7,235. One additional Earth-approaching comet also was found this year. High precision orbit predictions computed by NASA's Jet Propulsion Laboratory show that none of these objects are likely to hit Earth in the next century. However, 1,142 (of which 149 are larger than one kilometer in diameter) are in orbits that could become a hazard in the more distant future and warrant monitoring. NASA's goal is to find 90 percent of objects larger than one kilometer. Taking all the new discoveries into account, 818 near-Earth asteroids larger than one kilometer have been found to date, meaning the teams have found as many as 87 percent of the total existing objects.

More on NASA's Near Earth Object Program can be found at *http://neo.jpl.nasa.gov/*.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Develop missions in support of this Outcome, as demonstrated by completing the Mars Science Laboratory (MSL) flight hardware builds and flight system assemblies. | 7SSE5 Green | 8PS05 Green | 9PS4 Red | 10PS06 Yellow |
| Demonstrate progress in exploring the space environment to discover potential hazards to humans and to search for resources that would enable human presence. Progress will be evaluated by external expert review. | 7SSE8 Green | 8PS08 Green | 9PS9 Green | 10PS10 Green |
| Develop missions in support of this Outcome, as demonstrated by completing the first flight test of a warm gas lander testbed, to be used in support of lunar lander developments. | None | None | 9PS10 Green | 10PS12 Yellow |

**Why NASA did not achieve APG 10PS06:** The flight hardware build and flight system assembly of the Sample Analysis at Mars (SAM) instrument were not completed during the designated fiscal year, due to complications in the development of the Wide Range Pump (WRP) components of the instrument. The materials originally specified as the primary component of a high-speed, high-performance bearing proved to be inadequate to provide the necessary performance on the surface of Mars, and alternative bearing materials and components had to be researched and developed.

**Plans for achieving 10PS06:** The development of the new bearing designs has been completed and implemented, and the finalization of the flight hardware build has resumed. The final flight units are on schedule to be delivered in early December 2010.

**Why NASA did not achieve APG 10PS12:** The first integrated test of the Robotic Lunar Lander Development Project warm-gas test bed has been delayed primarily due to engineering analysis which required a re-design of the composite structure decks and subsequent fabrication delays of the structure.

**Plans for achieving 10PS12:** The redesign is complete, and the vendor fabrication of the composite decks was completed at the end of October 2010. A revised schedule for the first integrated test is expected in early FY 2011. In the meantime, good progress has been made with other key subsystems for the warm-gas test bed. For example, the project has successfully integrated the flight software, ground software, and guidance and control algorithms with the avionics and the sensors, and most notably, the propulsion system successfully completed acceptance testing. The first free-flight test is expected by March/April 2011.

# Sub-Goal 3D

## Discover the origin, structure, evolution, and destiny of the universe, and search for Earth-like planets.

| Summary of Ratings for Sub-Goal 3D | |
|---|---|
| 4 Outcomes | 9 APGs |
| Green = 4 | Green = 7 |
| Yellow = 0 | Yellow = 2 |
| Red = 0 | Red = 0 |
| White = 0 | White = 0 |

| FY 2010 Cost of Performance (Dollars in Millions) |
|---|
| $1,654.2 |

Using explorer missions and space-based telescopes, NASA enables research to understand the structure, content, and evolution of the universe. This research provides information about humankind's origins and the fundamental physics that govern the behavior of matter, energy, space, and time, and aids the search for life elsewhere in the universe. NASA-supported researchers try to answer three main questions:

*How does the Universe work?*

The Physics of the Cosmos Program contains missions that explore the extreme physical conditions of the universe, from black holes to dark energy. The Chandra X-ray Observatory, the third of NASA's Great Observatories, is joined by one of NASA's most recently launched missions, the Fermi Gamma-ray Space Telescope, as the main research instruments for this program.

*How did we get here?*

The Cosmic Origins program comprises projects that enable the study of how stars and galaxies came into being, how they evolve, and ultimately how they end their lives. The Hubble Space Telescope, Spitzer Space Telescope, and the Stratospheric Observatory for Infrared Astronomy (SOFIA) all support this research area.

*Are we alone?*

The Exoplanet Exploration program focuses on advancing scientific understanding of planets and planetary systems around other stars known as extrasolar planets, or simply exoplanets, with the goal of detecting habitable, Earth-like planets around other stars, determining how common such planets are, and searching for indicators that they might harbor life. The Kepler mission, launched in March 2009, is NASA's first dedicated Exoplanet Exploration mission.

Astrophysics also contributes to two crosscutting programs: the Explorer Program and Astrophysics Research. In partnership with the Heliophysics Division, missions under the Explorer Program provide opportunities for innovative science and fill the scientific gaps between the larger missions. For example, the Wide-field Infrared Survey Explorer (WISE), launched in December 2009, has surveyed the entire sky in the near-to-mid infrared, to find

Photo above: Ball Aerospace optical technician Scott Murray inspects six primary mirror segments, critical elements of the James Webb Space Telescope, prior to cryogenic testing in the X-ray and Cryogenic Facility at NASA's Marshall Space Flight Center. (Credit: NASA/D. Higginbotham)

the brightest, most distant infrared galaxies and the faintest stars in the solar neighborhood. Sponsored research programs prepare for the next generation of missions, through both theoretical research and applied technology investigations. They also exploit data from current missions and use suborbital science investigations to advance NASA science goals. Suborbital missions, an integral part of the research and analysis program, include sounding rocket, and balloon campaigns which provide ancillary measurements, demonstrate measurement technologies, and train future mission Principal Investigators and students.

## Benefits

NASA's Astrophysics missions, particularly the three Great Observatories: the Hubble Space Telescope, the Spitzer Space Telescope, and the Chandra X-ray Observatory, have provided researchers with new ways of looking at the universe so that they can expand knowledge about cosmic origins and fundamental physics. The study of the universe benefits the Nation's scientific research community by focusing research and advanced technology developments on optics, sensors, guidance systems, and propulsion systems. Some of these new and improved technologies enable ground-breaking capabilities, which are then available to both the commercial and defense sectors.

Stunning images produced from Astrophysics, operating missions continue to inspire the public, revealing the beauty of the universe and the science behind those images. The striking images from these observatories also are educational tools to help spark student interest in science, technology, engineering, and mathematics and serve to prominently illustrate the role of the United States in scientific exploration. NASA provides the tools to translate the science for the classroom and other learning venues in ways that meet educator needs.

## Risks to Achieving Sub-Goal 3D

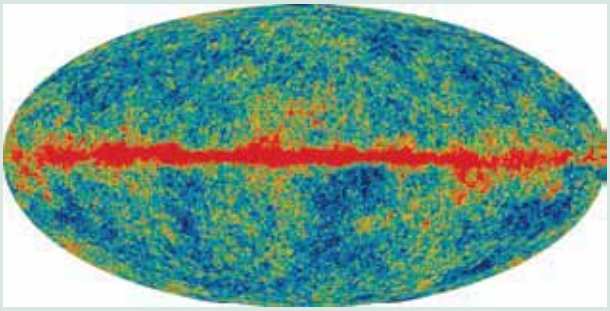
Of primary concern for the Astrophysics Division is the projected increased cost and schedule for the development of the James Webb Space Telescope (JWST). Because its annual budget is a substantial fraction of the Division budget, schedule delays and cost overruns on JWST could significantly impact the Division's ability to respond to the National Research Council's Astro2010 Decadal Survey.

The reduced mission frequency resulting from rising mission costs also impacts the systems approach to Astrophysics. NASA is aggressively exploring options to maintain a vital Explorers flight program. With the October 2010 release of the Explorer Announcement of Opportunity (AO), the program has taken a vital step toward maintaining an appropriate mix of small and large missions.

Finally, the Astrophysics Division, along with NASA's other Science divisions, continues to be concerned about the increased cost and reduced availability of expendable launch vehicle (ELV) options. The lack of reliable and affordable launch vehicle options may impair the Division's ability to sustain a scientifically and programmatically balanced portfolio during the next decade. Over the course of the last decade, the Delta II has been the workhorse for launching many robotic mid-sized spacecraft. Without this option, NASA has access only to costlier evolved ELVs (Delta IV, Atlas V). Possible cost growth in the evolved ELV class is an additional source of concern. These problems cannot be avoided until new commercial launch vehicles become available, potentially reducing the cost of launching missions.

## *Outcome 3D.1: Progress in understanding the origin and destiny of the universe, phenomena near black holes, and the nature of gravity.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |



Credit: NASA/WMAP Science Team

WMAP imaged fluctuations of the cosmic microwave background radiation at 94 GHz as to produce this full-sky temperature map. The color scale is +-200 microKelvin. The red stripe in the middle is emission from our the Milky Way galaxy. WMAP was designed to operate for only four years, but because of flawless operations and excellent science yield, NASA extended the mission.

**An aging mission makes discoveries at the earliest moments of the universe**

In January 2010, the Wilkinson Microwave Anistropy Probe (WMAP) team celebrated the mission's seventh birthday by publishing the accumulated, compelling results about the origin and destiny of the universe.

The satellite is observing a radiation that is a relic remnant from the Big Bang called the cosmic microwave background radiation. One of the key predictions of the Big Bang model is that most of the helium in the universe was synthesized in the hot early universe only a few minutes after the Big Bang. Previously, scientists studied old stars to infer the helium abundance before there were stars. WMAP data, in combination with other experiments, show the effects of helium in the microwave patterns on the sky indicating the presence of helium long before the first stars formed.

The team also detected in the data signatures of the inflationary expansion of the universe that is believed to have occurred at the beginning of time. According to inflationary models, intensity fluctuations of the relic radiation should be more intense over large patches of the sky compared to those on small patches. This agrees with the data.

The WMAP results also affect understanding of fundamental physics by limiting the number of neutrino-like particles in the universe. Neutrinos are nearly massless elementary particles that move at or near the speed of light. They permeate the universe in large quantity but they interact very weakly with atomic matter. How many such particle species existed in the early universe has been an open question in physics. WMAP data now limits the number of such species to less than six.

More WMAP science results are available at *http://map.gsfc.nasa.gov/news/*.

**NASA's Fermi lifts the fog**

A new study of the uniform fog of gamma rays from sources outside the Milky Way galaxy shows that less than a third of the emission arises from what astronomers considered the most likely suspects—supermassive black hole-powered jets from active galaxies.

The sky glows in gamma rays even far away from bright sources, such as pulsars and gas clouds within the Milky Way galaxy or the most luminous active galaxies. According to the conventional explanation, this background glow represents the accumulated emission of a vast number of active galaxies that are simply too faint and too distant to be resolved as discrete gamma-ray sources. Thanks to NASA's Fermi Gamma-ray Space Telescope, scientists now know this is not the case.

Because of its breakthrough capabilities, the Fermi Large Area Telescope (LAT) maps the entire gamma-ray sky continuously, looking ever more deeply into the universe and tracking all sources as they vary in intensity. Active galaxies possess central black holes containing millions to billions of times the Sun's mass. As matter falls toward the black hole, some of it becomes redirected into jets of particles traveling near the speed of light. These particles can produce gamma rays.

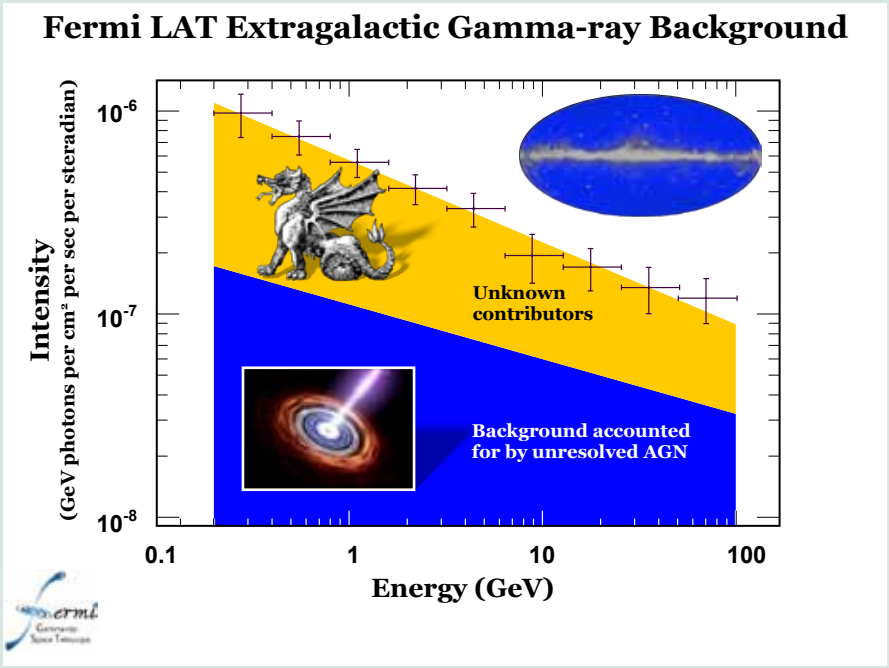
There also are other potential sources for extragalactic gamma-ray background: particle acceleration occurring in normal star-forming galaxies is a strong contender; particle acceleration during the final assembly of the large-scale structure observed today, for example, where clusters of galaxies are merging together; or dark matter, the

mysterious substance that neither produces nor obscures light but whose gravity corrals normal matter. Dark matter may be a type of as-yet-unknown subatomic particle. If that's true, dark matter particles should interact with each other in a way that produces gamma rays. Improved analysis and extra sky exposure will enable scientists to address these potential contributions.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Demonstrate progress in understanding the origin and destiny of the universe, phenomena near black holes, and the nature of gravity. Progress will be evaluated by external expert review. | 7UNIV1 Green | 8AS01 Green | 9AS1 Green | 10AS01 Green |
| Develop missions in support of this Outcome, as demonstrated by completing the NuSTAR Critical Design Review (CDR). | None | None | None | 10AS02 Green |
| Conduct the flight program in support of this Outcome, as demonstrated by achieving mission success criteria for Fermi. | None | None | None | 10AS04 Green |

Centuries ago map makers marked distant regions with, "Here be dragons," warning explorers that they would be traveling into the unknown. Astronomers using NASA's Fermi telescope find themselves in the same situation as they study the ever-present fog of gamma rays from sources outside the galaxy. The Fermi data invalidated a once-popular explanation for the extragalactic gamma-ray background, showing that jets from active galaxies play only a minor role in producing the emission.

Credit: NASA/DOE/Fermi LAT Collaboration



## *Outcome 3D.2: Progress in understanding how the first stars and galaxies formed, and how they changed over time into the objects recognized in the present universe.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |

Credit: NASA/ESA/G. Illingworth and R. Bouwens, UC Santa Cruz/HUDF09 Team

This image was taken in late August 2009 with Hubble's Wide Field Camera 3. The faintest and reddest objects are galaxies that correspond to "look-back times" of about 12.9 to 13.1 billion years ago. These galaxies are much smaller than the Milky Way galaxy and have populations of stars that are intrinsically very blue. This may indicate the galaxies are so primordial that they are deficient in heavier elements and, as a result, are relatively free of dust that reddens light through scattering.

**Hubble on the edge of the observable universe**

The NASA–European Space Agency Hubble Space Telescope smashed the distance limit for galaxies and uncovered a primordial population of compact and ultra-blue galaxies that have never been seen before. With this data the astronomers have entered uncharted territory ripe for discoveries about young galaxies and galaxy formation.

The deeper Hubble looks into space, the farther back in time it looks, making it a powerful "time machine" that allows astronomers to see galaxies as they were 13 billion years ago, just 600 million to 800 million years after the Big Bang. At least one of the newly discovered galaxies lies beyond a redshift of 8.5, or 13.1 billion years ago. These discoveries push back the known time of formation of the first galaxies to less than 600 million years after the Big Bang. The deep observations also demonstrate the progressive buildup of galaxies and provide further support for the hierarchical model of galaxy assembly where small objects merge to form bigger objects over a smooth and steady, but still dramatic, process of collision and agglomeration, as these small building blocks fuse into the larger galaxies known today. In the future, the much more powerful JWST will allow astronomers to study the detailed nature of such primordial galaxies and discover many more even farther away. The recently completely WISE mission will produce a catalog of rich sources on which JWST will conduct follow-up observations.

More on this story is available at *http://hubblesite.org/newscenter/archive/releases/2010/02/full/*.

**Fermi closes in on source of cosmic rays**

New images from NASA's Fermi Gamma-ray Space Telescope show where supernova remnants emit radiation a billion times more energetic than visible light. The images bring scientists an important step closer to solving the mystery of the source of some of the most energetic particles in the universe—cosmic rays.

Cosmic rays are part of the most extreme environments of the dynamic and diverse universe, where nature harnesses incredible energies that form black holes, forge galaxies, and compose dark matter. Cosmic rays consist mainly of protons that move through space at nearly the speed of light. In their journey across the galaxy, the particles are deflected by magnetic fields. This scrambles their paths and masks their origins.

In 1949, the Fermi telescope's namesake, physicist Enrico Fermi, suggested that the highest-energy cosmic rays were accelerated in the magnetic fields of gas clouds. In the decades that followed, astrophysicists showed that supernova remnants are the best candidate sites in the galaxy for this process. Young supernova remnants seem to possess both stronger magnetic fields and the highest-energy cosmic rays. Stronger fields can keep the highest-energy particles in the remnant's shock wave long enough to speed them to the energies observed. The Fermi telescope observations show billion-electron-volt (GeV) gamma rays (gamma rays are produced when cosmic rays collide with interstellar gas) coming from places where the remnants are known to be interacting with cold, dense gas clouds. These observations validate the hypothesis that supernova remnants act as enormous accelerators for cosmic particles.

More on this story is available at *http://www.nasa.gov/mission_pages/GLAST/news/cosmic-rays-source.html*.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Demonstrate progress in understanding how the first stars and galaxies formed and how they changed over time into the objects we recognize in the present universe. Progress will be evaluated by external expert review. | 7UNIV5 Green | 8AS03 Green | 9AS3 Green | 10AS05 Green |
| Develop missions in support of this Outcome, as demonstrated by completing the James Webb Space Telescope (JWST) Optical Telescope Element Critical Design Review (CDR). | 7UNIV4 Green | 8AS04 Green | 9AS4 Green | 10AS06 Green |
| Develop missions in support of this Outcome, as demonstrated by completing the first competed Early Science observations on the Stratospheric Observatory for Infrared Astronomy (SOFIA). | None | None | 9AS5 Yellow | 10AS07 Yellow |
| Conduct the flight program in support of this Outcome, as demonstrated by achieving mission success criteria for WISE. | None | None | None | 10AS08 Yellow |

**Why NASA did not achieve APG 10AS07:** Technical problems with the telescope cavity door actuator on the SOFIA aircraft, due to quality control issues at the vendor of the actuator, led to increased time required for flight testing and certification for open-door flight at the altitude required for early science. NASA worked directly with the vendor to address and resolve the quality control issues.

**Plans for achieving 10AS07:** Flight testing of the full flight envelope has been completed, and the first image has been acquired by the telescope in flight. The program is currently on track for the first early science observation by December 2010.

**Why NASA did not achieve APG 10AS08:** WISE has met all of its minimum success criteria and is considered to be a successful mission by both NASA and the science community. WISE has met all of its full mission success criteria, with the exception of the sensitivity requirement in band 4 (23 micrometers). The requirement was to achieve sensitivity of 4 millijansky (mJy) over 95 percent of the sky. The actual achieved sensitivity in band 4 was 4.8 mJy over 95 percent of the sky. The shortfall has an insignificant effect on the scientific productivity of the WISE mission. The loss of sensitivity compromised the ability of WISE to detect objects as faint as those that would otherwise have been seen, especially affecting measurements of galaxies and dusty disks surrounding young stars. Relatively faint galaxies missing in one area were observed elsewhere in the sky, where repeated sky coverage yielded deeper observations. However, an analogous compensation method did not apply to young stars because these objects are located only in certain regions. Consequently, WISE did not observe as many faint dusty disks as had been anticipated.

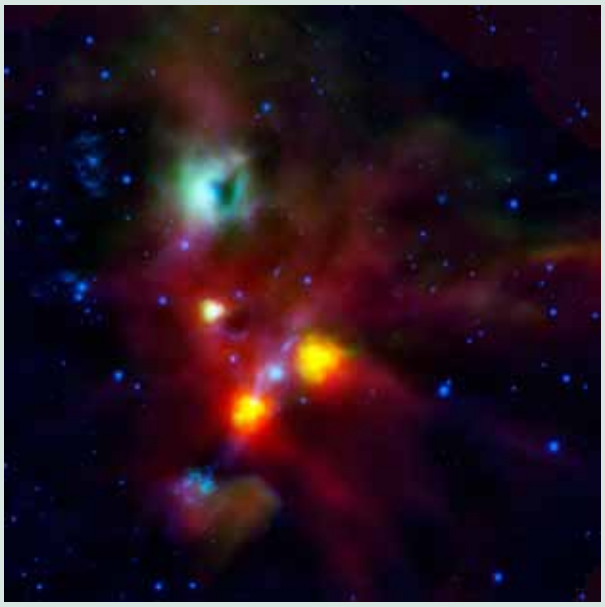
**Plans for achieving 10AS08:** WISE has completed its mission.

This composite image shows the Cassiopeia A supernova remnant across the spectrum: Gamma rays (magenta) from NASA's Fermi Gamma-ray Space Telescope; X-rays (blue, green) from NASA's Chandra X-ray Observatory; visible light (yellow) from the Hubble Space Telescope; infrared (red) from NASA's Spitzer Space Telescope; and radio (orange) from the Very Large Array near Socorro, New Mexico. Fermi's Large Area Telescope spied GEV gamma rays from Cassiopeia A, which is a youthful 330 years old. Fermi allows astronomers to compare emissions from remnants of different ages and in environments.

Credit: NASA/DOE/Fermi LAT Collaboration, CXC/SAO/JPL-Caltech/Steward/O. Krause et al., and NRAO/AUI

## *Outcome 3D.3: Progress in understanding how individual stars form and how those processes ultimately affect the formation of planetary systems.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |



Credit: ESA/NASA/JPL-Caltech/Univ. of Toledo

The dark hole seen in the green cloud (NGC 1999) at the top of this image was likely carved out by multiple jets and blasts of radiation. For most of the 20th century, black patches were known to be dense clouds of dust and gas that block light from passing through. Astronomers originally thought the hole was a really dark cloud, but this new infrared picture from Herschel, a European Space Agency mission, and the National Optical Astronomy Observatory on Kitt Peak near Tucson, Arizona, reveals that the dark spot is actually a gap in a "nest" of gas and dust containing fledgling stars. The red, filamentary glow extending through the middle of the image is a cloud of cold, dense gas and dust—the raw material from which new stars are forming. NASA played a key role in the development of two of Herschel's three instruments and will make important contributions to data and science analyses.

**Herschel provides glimpse into the end of star-forming processes**

The Herschel Space Observatory has made an unexpected discovery: a gaping hole in the clouds surrounding a batch of young stars. The hole has provided astronomers with a surprising glimpse into the end of the star-forming process.

Although astronomers have seen jets and winds of gas streaming from young stars in the past, it has always been a mystery exactly how a star uses the jets to blow away its surroundings and emerge from its birth cloud. For the first time, Herschel may be seeing an unexpected step in this process. A cloud of bright reflective gas known to astronomers as NGC 1999 sits next to a black patch of sky.

Investigating further using ground-based telescopes, astronomers found the same story no matter how they looked. This patch looks black not because it is a dense pocket of gas but because it is truly empty space. Astronomers think that the hole must have been opened when the narrow jets of gas from some of the young stars in the region punctured the sheet of dust and gas that forms NGC 1999. The powerful radiation from a nearby adolescent star may also have helped to clear the hole. Whatever the precise chain of events, it could be an important glimpse into the way newborn stars rip apart their birth clouds.

More on this story is available at *http://www.nasa.gov/mission_pages/herschel/herschel20100511.html*.

**Spitzer spies a 'flying dragon' smoldering with secret star birth**

NASA's Spitzer Space Telescope has revealed a cosmic cloud shaped like a flying dragon that has a secret burning behind its dark scales. Stars are forming in this cloud, dubbed M17 SWex, about as fast as in a neighboring, dazzling nebula called M17 that is illuminated by giant stars, but no similar stellar behemoths have yet emerged to set the dragon's dusty innards aglow. Astronomers believe that they have captured this cloud in a very early phase of star formation, before its most massive stars have ignited. A wave of massive star formation, possibly caused by the crossing of a grand spiral arm of the Milky Way galaxy, appears to be rippling through the M17 complex. This surge has not yet reached the beastly cloud, establishing M17 SWex as a compelling place to explore the origins of massive stars. Spitzer's infrared vision has shown that M17 and M17 SWex are some of the busiest star-making factories in the Milky Way. Spitzer has detected the infrared light given off by heated dust in M17 SWex,

signifying 488 newly forming stars, most of which have grown disks of material around their middles that may give rise to planets. More than 200 of these younglings will become class B stars, larger and hotter than the Sun. Conspicuously absent from M17 SWex, however, are class O stars, the bluest, hottest, and biggest of new stars. Although relatively rare in the cosmos, O stars are what light up neighboring M17, and given all the star-forming material in M17 SWex, these behemoths should be on the scene there as well. Their absence hints that these colossal stars may form later, perhaps needing an extra impetus to nudge them into existence.

More on this story is available at *http://www.spitzer.caltech.edu/news/1143-feature10-09-Spitzer-Spies-a-Flying-Dragon-Smoldering-with-Secret-Star-Birth*.

Credit: NASA/JPL-Caltech/M. Povich, Penn State Univ.

A black, dragon-shaped cloud of dust, M17 SWex, seems to fly out from a bright explosion in this infrared light image (top) from Spitzer, a creature that is entirely cloaked in shadow when viewed in the visible part of the spectrum (bottom). While it is forming stars at a furious rate, it has not yet spawned the most massive type of stars, O stars, that light M17 in the lower center of both images. At the far left of the field lies a giant "bubble" blown by blue O stars, aged some two to five million years. Meanwhile, the budding stars in M17 SWex have not yet celebrated their one millionth birthdays—truly infants in the stellar sense.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Develop missions in support of this Outcome, as demonstrated by completing the James Webb Space Telescope (JWST) Optical Telescope Element Critical Design Review (CDR). | 7UNIV4 Green | 8AS04 Green | 9AS4 Green | 10AS06 Green |
| Develop missions in support of this Outcome, as demonstrated by completing the first competed Early Science observations on the Stratospheric Observatory for Infrared Astronomy (SOFIA). | None | None | 9AS5 Yellow | 10AS07 Yellow |
| Demonstrate progress in understanding how individual stars form and how those processes ultimately affect the formation of planetary systems. Progress will be evaluated by external expert review. | 7UNIV6 Green | 8AS06 Green | 9AS6 Green | 9AS09 Green |

**Why NASA did not achieve APG 10AS07:** Technical problems with the telescope cavity door actuator on the SOFIA aircraft, due to quality control issues at the vendor of the actuator, led to increased time required for flight testing and certification for open-door flight at the altitude required for early science. NASA worked directly with the vendor to address and resolve the quality control issues.

**Plans for achieving 10AS07:** Flight testing of the full flight envelope has been completed, and the first image has been acquired by the telescope in flight. The program is currently on track for the first early science observation by December 2010.

## *Outcome 3D.4: Progress in creating a census of extrasolar planets and measuring their properties.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Yellow | Green | Green | Green |

Credit: NASA/JPL-Caltech/R. Hurt, SSC/Caltech

The unusual, methane-free world GJ 436b is partially eclipsed by its star in this artist's concept. Scientists writing about the planet in the April 22, 2010, issue of Nature said that they were puzzled by planet's atmosphere because previous models showed that the carbon should have been in the form of methane. GJ 436b, located 33 light-years away in the constellation Leo, is providing data on faraway planets that will show what is really going on in their atmospheres.

**Spitzer discovers a planet is missing an ingredient**

NASA's Spitzer Space Telescope has discovered something odd about a distant planet: The planet lacks methane, an ingredient common to many of the planets in Earth's solar system. The discovery brings astronomers one step closer to probing the atmospheres of distant planets the size of Earth. Eventually, a larger space telescope could use the same kind of technique to search smaller, Earth-like worlds for methane and other chemical signs of life, such as water, oxygen and carbon dioxide. The methane-free planet, called GJ 436b, is about the size of Neptune, making it the smallest distant planet that any telescope has successfully analyzed. Any world with the common atmospheric mix of hydrogen, carbon, and oxygen, and a temperature up to 1,000 Kelvin (1,340 degrees Fahrenheit) is expected to have a large amount of methane and a small amount of carbon monoxide. Surprisingly, Spitzer observations found just the opposite—carbon monoxide but no methane.

For more on this story go to *http://spitzer.caltech.edu/news/1110-ssc2010-05--This-Planet-Tastes-Funny-According-to-Spitzer-Telescope*.

**Evolution of an unusual multi-planet system**

Almost all of the planets within Earth's solar system orbit within the same plane, the natural byproduct of a disk of gas and dust around a young star collapsing down to form planets. This follows the astronomers' theories of how multi-planet systems evolve. In May 2010, astronomers reported the discovery of a planetary system that impacts these theories—a planetary system way out of tilt, where the orbits of two planets are at a steep angle to each other.

For just over a decade, astronomers have known that three Jupiter-sized planets (designated Upsilon Andromedae b, c, and d) orbit the yellow-white star Upsilon Andromedae. Combining data from the Hubble Space Telescope and ground-based telescopes, astronomers have determined the exact masses of Upsilon Andromedae c and d, and much more startling, found that the orbits of planets c and d are inclined by 30 degrees with respect to each other. This research marks the first time that astronomers have measured the "mutual inclination" of two planets orbiting another star. They have also uncovered hints that a fourth planet, e, orbits the star much farther out. Several different gravitational scenarios could be responsible for the surprisingly inclined orbits, including interactions occurring from the inward migration of planets, the ejection of other planets from the system through planet-planet scattering, or disruption from the parent star's binary companion star. Further research is required to understand these observations, but they already offer exciting insight into the creation and evolution of planetary systems.

For more on this story go to *http://hubblesite.org/newscenter/archive/releases/2010/17/full/*.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Demonstrate progress in creating a census of extra-solar planets and measuring their properties. Progress will be evaluated by external expert review. | 7UNIV7 Green | 8AS07 Green | 9AS7 Green | 10AS10 Green |

# Sub-Goal 3E

## Advance knowledge in the fundamental disciplines of aeronautics, and develop technologies for safer aircraft and higher capacity airspace systems.

| Summary of Ratings for Sub-Goal 3E | |
|---|---|
| 5 Outcomes | 13 APGs |
| Green = 4 | Green = 10 |
| Yellow = 1 | Yellow = 3 |
| Red = 0 | Red = 0 |
| White = 0 | White = 0 |

| FY 2010 Cost of Performance (Dollars in Millions) |
|---|
| $697.0 |

NASA research continues to contribute directly to aeronautics breakthroughs that impact public safety and the Nation's economy. A key enabler for American commerce and mobility, U.S. commercial aviation is vital to the Nation's well-being. As NASA's lead organization for aeronautics research, NASA's Aeronautics Research Mission Directorate (ARMD) conducts cutting-edge research to generate the innovative concepts, tools, and technologies that will enable revolutionary advances in future aircraft as well as the airspace through which they fly.

Each of NASA's five aeronautics programs plays a significant role in addressing Sub-goal 3E:

- The Fundamental Aeronautics Program seeks to continually improve technology that can be integrated into today's state of the art aircraft, while enabling game-changing concepts for future generations of aircraft technologies such as Hybrid Wing Body airframes which promise reduced drag (thus improving fuel burn), and open rotor engines which offer the promise of 20 percent fuel burn reduction compared to today's aircraft. NASA is addressing key challenges to enable new rotorcraft and supersonic aircraft, and conducting foundational research on hypersonic flight at seven times the speed of sound. Another key research goal is to enable the use of synthetic and bio-derived alternatives to the petroleum-derived fuel that all jet aircraft have used for the last 60 years.
- The Aviation Safety Program conducts research to ensure that aircraft and operational procedures maintain the high level of safety which the American public has come to count on. NASA performs research in safety issues that span aircraft operations, air traffic procedures, and environmental hazards. This research seeks to not only improve the intrinsic in-flight and on-ground safety of current and future aircraft, but to overcome technological barriers that would otherwise constrain the full realization of the next generation air transportation system.
- The Airspace Systems Program aims to improve efficiency and reduce environmental impact of aviation through improved air traffic management concepts and technologies covering gate-to-gate operations on the airport surface, on runways, in the dense terminal area, and in the many en route sectors of the national airspace. In order to achieve these improvements, safe and efficient operational concepts, technologies, and procedures must be developed, validated, and certified for operational use.

Photo above: Ice forms on a vertical stabilizer in NASA Glenn Research Center's Icing Research Tunnel. (Credit: NASA)

- The Aeronautics Test Program (ATP) manages the testing capabilities of one of the largest, most versatile and comprehensive set of research facilities in the United States. These facilities are used by NASA programs, other Federal agencies, and the private sector to test and evaluate research concepts and technologies. ATP manages current facilities and makes strategic investments to ensure that both NASA and national interests in the public and private sectors have ready access to comprehensive testing in state-of-the-art ground test facilities and with flight research assets.
- The Integrated Systems Research Program (ISRP) evaluates and selects the most promising concepts emerging from the foundational research programs for integration at the systems level. ISRP will test integrated systems in relevant environments to demonstrate that the combined benefits of these new concepts are in fact greater than the sum of their individual parts. By focusing on technologies that have already proven their merit at the foundational level, this program will help transition those technologies more quickly to the aviation community, as well as inform future foundational research needs. ISRP will also advance capabilities to design and integrate complex aviation systems.

# Benefits

NASA's aeronautics program ensures long-term focus in fundamental research in traditional aeronautical disciplines and relevant emerging fields, as well as integration into multidisciplinary system-level capabilities for broad application. This approach will enable revolutionary change to both the airspace system and the aircraft that fly within it, ultimately leading to a safer, more environmentally friendly, and more efficient national air transportation system. In order to accomplish this research, ARMD reaches out to the greater aeronautics community through the NASA Research Announcement (NRA) process and fosters collaborative partnerships with the academic and private sector communities while also providing support for science, technology, engineering, and math departments. By directly connecting students with NASA researchers and our industrial partners, NASA aeronautics research helps future workforce needs by inspiring students to choose a career in the aerospace industry.

# Risks to Achieving Sub-Goal 3E

NASA pursues challenging, cutting-edge technology advances and aeronautics research goals that are inherently high risk. Although ARMD may not reach some planned program goals due to this high technical risk, lessons learned nevertheless advance the state of knowledge for NASA programs. The Agency and the Nation are thus able to make informed decisions on committing research resources to better ensure the achievement of national goals and objectives.

NASA's aeronautics partnerships provide many benefits, but they also introduce external dependencies that influence schedules and research output. In particular, research may depend on contributions from partner agencies to conduct validation studies and to implement technologies once transitioned. NASA mitigates these risks through continual coordination with its partners in academia, industry, and other Federal agencies to ensure that the Agency is moving forward on the right challenges and improving the transition of research results to users.

## *Outcome 3E.1: By 2016, identify and develop tools, methods, and technologies for improving overall aircraft safety of new and legacy vehicles operating in the Next Generation Air Transportation System (projected for the year 2025).*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |

Credit: NASA

The Integrated Intelligent Flight Deck includes systematic incorporation of integrated displays and interactions, decision-support functions, information management and abstraction, and appropriate human/automation function allocations. The future flight deck system is aware of the vehicle, operator, and airspace system state and responds appropriately. The system senses internal and external hazards, evaluates them, and provides key information to facilitate timely and appropriate responses.

**NASA explores how aircraft age**

In FY 2010, the Aging Aircraft and Durability Project developed an innovative method for modeling the effects of water penetrating epoxy matrix resins (a component of advanced structural composites) and their ability to adhere to each other.

Aircraft aging is a significant national issue. For economic reasons, commercial airline carriers and the Department of Defense (DoD) are flying their vehicles longer, often exceeding the original design service life of the vehicles. The average age of the commercial fleet, which reduced after 9/11 as older vehicles were parked, is increasing, particularly in the wide-body class. The DoD is replacing its fleet at less than half the rate required to even maintain the current average age.

Emerging civilian and military aircraft are introducing advanced material systems, fabrication techniques, and structural configurations for which there is very limited service history, and there is concern over the ability to ensure continued airworthiness of these aircraft over their life cycles. Simulation results demonstrated that this new modeling technique provides qualitative predictive capability for the changes in surface energy of epoxy matrix resins that can affect the adhesion characteristics of bonded interfaces, such as those encountered in aircraft structural assemblies.

Understanding how moisture present in the epoxy matrix resins changes the surface energy at the interface of bonded areas can aid in the development of new epoxy chemistries or surface treatments that resist the negative effects of moisture penetration to provide more durable and reliable bonded assemblies.

**NASA experiments support more capable and safer flight deck systems**

The Integrated Intelligent Flight Deck Project published flight deck guidelines, information, and display requirements that meet NextGen operational concept needs. The project based these guidelines on data collected via human-in-the-loop studies in flight deck simulators that replicated the higher traffic densities and four-dimensional trajectory-based operations and equivalent visual NextGen-based environments, utilizing advanced flight deck data communication, display, indication, and alerting technologies. NASA also conducted experiments with flight crews and controllers utilizing various levels of flight-deck automation. By providing these results to industry-wide and FAA-sponsored technical committees, NASA helps to inform and generate authorized operational requirements and certification standards for new technologies and procedures.

**NASA improves aircraft safety**

The Integrated Resilient Aircraft Control Project, which conducts research to advance the state of aircraft flight control to provide onboard control resilience for ensuring safe flight in the presence of unforeseen, adverse conditions, developed a tool suite that would be used to locate failure points in the flight envelope for a chosen adaptive control system and a set of adverse events. The suite is an integrated software package designed to efficiently analyze dynamic systems subject to uncertainty and offers several complementary methods for performing

a variety of uncertainty quantification tasks. Details of the dynamics involved in an aircraft loss of control situation are required to better understand how a system can best regain control without further exacerbating the situation.

Results of an investigation using the integrated software package demonstrated confidence levels as good as what can be achieved using direct Monte-Carlo simulation techniques with a factor of ten reduction in computing time over direct Monte Carlo techniques. The Integrated Vehicle Health Management Project developed an advanced hybrid diagnostic system for electromechanical actuators (EMA) that covers a wide variety of faults typical to this type of actuator. The system combines both qualitative and quantitative diagnostic approaches to achieve low false positive/false negative detection rates and a high accuracy of diagnostic output. After conducting validation experiments using 320 different nominal and fault scenarios, the results showed very low rates for false positive and false negative fault detections and over 95 percent diagnostic accuracy. As EMAs become increasingly applied to such aircraft critical roles as control surface actuation, having a reliable diagnostic system monitoring their performance becomes essential. The work paves the way for development of more capable EMA health management systems.

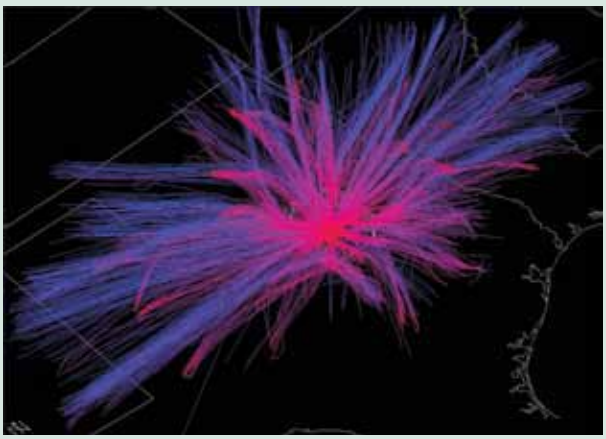
| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Using 2008 as a baseline, demonstrate, on a representative current-generation electromechanical system test bed, improved IVHM via Bayesian methods and/or models for varying operating conditions and demonstrate fault detection/diagnosis on at least three faults types and examine tradeoff between accuracy and diagnosis time. | 7AT1 Green | 8AT04 Green | 9AT1 Green | 10AT01 Green |
| Develop an atomistically-based model capable of predicting within 25% the degradation caused by environmental effects on interfaces in selected polymer matrix composite materials. | 7AT01 Green | None | 9AT02 Green | 10AT02 Yellow |
| Deliver and validate through analysis flight deck guidelines, information, and display requirements that meet NextGen operational needs as established in 2007 baseline assessment, and without a measurable increase to safety risk. | 7AT1 Green | 8AT02 Green | 9AT3 Green | 10AT03 Green |
| Develop a tool suite that provides an order of magnitude reduction in analysis time over current Monte-Carlo simulation methods that would be used to locate failure points in the flight envelope for a chosen adaptive control system and a set of adverse events. | 7AT1 Green | None | 9AT4 Green | 10AT04 Green |

**Why NASA did not achieve APG 10AT02:** This effort attempted to significantly push the state-of-the-art in atomistic-based computational modeling, and application of such models to predict the effects of aging of epoxy matrix resins used on commercial aircraft. The computational model that was developed predicted a reduction in surface energy over time, which is consistent with physical aging phenomenon reported in the literature. While the surface energy predictions differed somewhat from the measured values, experiments on lap shear specimen data for both surface energy and lap shear strength validated the predicted trends. Due to variability in computational and experimental results, it was not possible to validate the computational model for accurate quantitative prediction of physical aging to the performance level defined in the green success criteria.

**Plans for achieving 10AT02:** The activity as defined in the APG is complete. The performance level defined in the yellow success criteria was achieved. Since this was a "stretch-goal" no plans exist to continue to attempt to reach the absolute accuracy reflecting a green success criteria. However, the results obtained will inform future research in atomistic computational modeling. Further, successful prediction of the trends observed in experiments show that atomistic computational modeling may indeed be a valuable tool to guide new material development for improved durability.

## *Outcome 3E.2: By 2016, develop and demonstrate future concepts, capabilities, and technologies that will enable major increases in air traffic management effectiveness, flexibility, and efficiency, while maintaining safety, to meet capacity and mobility requirements of the Next Generation Air Transportation System.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |



Credit: NASA

This flower-shaped image shows flights in and out of the Dallas–Ft. Worth International Airport. The red lines indicate low-altitude flights and the blue line high-altitude flights.

**NASA continues research to improve air traffic control**

NASA researchers at Ames and Langley Research Centers conducted a coordinated set of simulations of advanced NextGen concepts to investigate allocation of separation functions between airborne and ground-based systems and human operators and automation. It is fully expected that the future national airspace system must manage, at any given time, a much larger number of flights requiring separation capability resident in both the ground control facilities and cockpit.

These experiments, which simulated the flow of air traffic across eight air traffic control sectors in 14 operational scenarios, conducted an initial assessment of the performance of those capabilities. These simulations investigated: use of ground-based automation for conflict detection and resolution, airborne surveillance-enabled operation for self-separation by the flight-deck, and advanced trajectory-based operations at approximately twice the current maximum capacity, with integrated metering, weather, and conflict avoidance. This simulation also addressed the NextGen High Value Focus Area of Air/Ground and Human/Machine Functional Allocation as identified by the Joint Planning and Development Office (JPDO). The integrated simulations illustrated significant cross-center collaboration, had unprecedented commonality in experiment designs for comparison of disparate concepts, and matured both ground-based and flight-deck conflict detection and resolution algorithms and procedures.

The participants supporting these simulations included 48 domestic and international airline pilots, and 20 active FAA supervisors and retired controllers. The scenarios studied one and a half to two times the traffic density, time-based metering, and trajectory change events, collecting 264 pilot-hours of airborne based and 300 hours of ground based simulation data along with extensive questionnaire data.

Common scenarios represented a significant increase in airspace demand over current operations. Where comparisons were possible with current operations, no substantial differences in performance or operator acceptability were observed. Mean schedule conformance and flight path deviation were considered adequate for both approaches. Conflict detection warning times and resolution times were mostly adequate. Some situations, designed to stress the concepts and assess safety implications, were identified in which safety was compromised and/or workload was rated as being unacceptable in both experiments. These findings will be used to enhance the algorithms and future simulation designs to address the NextGen automation needs while maintaining safety and reducing workload.

This simulation is the first in a series of culminating simulations of advanced NextGen concepts to investigate allocation of separation functions between airborne and ground-based systems and human operators and automation.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Conduct simulations of automated separation assurance with sequencing, spacing, and scheduling constraints. | None | 8AT05 Green | 9AT5 Green | 10AT05 Green |
| Determine the feasibility and benefits of one or more candidate Multi-Sector Planner concepts. | None | None | None | 10AT06 Green |
| Produce a report on the human-in-the-loop simulation and model results for the Denver Field Trial. | None | None | None | 10AT14 Green |

## NASA in the Spotlight

### *NASA Helps Make Helicopters Safer*

How do you make a helicopter safer to fly? First, you crash one.

In December 2009, NASA aeronautics researchers recently dropped a small helicopter from a height of 35 feet to see whether an expandable honeycomb cushion called a deployable energy absorber could lessen the destructive force of a crash. On impact, the helicopter's skid landing gear bent outward, but the cushion attached to its belly kept the rotorcraft's bottom from touching the ground. Four crash test dummies along for the ride appeared only a little worse for the wear. The test conditions imitated what would be a relatively severe helicopter crash. They recycled the helicopter and dropped it again in 2010, but without the deployable energy absorber attached, in order to compare the results.

For more on this story go to *http://www.nasa.gov/topics/aeronautics/features/helo-droptest.html*.

Photo above: Researchers at NASA's Langley Research Center tested the deployable energy absorber with the help of a helicopter donated by the Army, crash test dummies from the Applied Physics Laboratory in Laurel, Maryland, and a 240-foot-tall structure once used to teach astronauts how to land on the Moon. (Credit: NASA/S. Smith)

## *Outcome 3E.3: By 2016, develop multi-disciplinary analysis and design tools and new technologies, enabling better vehicle performance (e.g., efficiency, environmental, civil competitiveness, productivity, and reliability) in multiple flight regimes and within a variety of transportation system architectures.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |

Credit: NASA

This artist's concept shows a truss-braced wing (TBW), or strut-braced wing (SBW) aircraft. Research results suggest an SBW can reduce fuel weight by 15 percent and a TBW by almost 20 percent due to reduced drag.

NASA's Fundamental Aeronautics Program (FAP) in ARMD conducts long-term foundational research and technology development in all flight regimes to address major national challenges of next generation and future air transportation systems. These advanced air transportation systems demand environmentally sensible aerospace technologies that demonstrate significantly better performance and higher fuel efficiencies, and the use of alternative fuels, to mitigate the vexing problem of noise and emissions. To meet these and other important national challenges, FAP, along with industry and university partners, is focusing on developing revolutionary technologies, tools and capabilities to enable dramatic changes in air vehicle design and propulsion systems for vehicles across all flight speed regimes. A particular class of these advanced air vehicle technologies for airframe and propulsion concepts, and other enabling complementary technologies are targeted for entry into commercial service in the N+3 or 2030–2035 timeframe resulting from fundamental research conducted now.

**Concept studies guide the way to the future of aeronautics technologies**

To achieve this goal, FAP conducts both in-house cross-cutting and foundational research through two of its four projects: the Subsonic Fixed Wing (SFW) Project and the Supersonics (SUP) Project, as well as with industry and academia by means of the NASA Research Announcement (NRA) procurement vehicle in a time-phased approach. The primary objective of the Phase I and Phase II NRA solicitations are to stimulate thinking and creativity in developing revolutionary aircraft solutions to significant problems in the future (energy efficiency, environmental compatibility, operations) and determine high-payoff technologies and research opportunities to address these national air transportation system challenges. Thus, Phase I competed for N+3 Concept Studies NRA awards were made to four subsonic aircraft teams and two supersonic aircraft teams to study advanced aircraft concepts that can address very stringent performance and environmental goals for air vehicles that are slated to enter service in the 2035 timeframe.

The results of Phase I N+3 18-month Advanced Concept Studies Completed revealed a range of fascinating technology concepts, tools, and capabilities with the potential to enable revolutionary air vehicle designs and propulsion systems for future air transportation systems. A short list of the key potential technologies that resulted from the N+3 Concept Studies' results includes:

Subsonic Fixed Wing Aircraft:

- Uniquely enabling concepts/technologies: strut/truss-braced wing, double-bubble aircraft, hybrid electric propulsion;
- Alternative energy—conventional/biofuel most prevalent plus hybrid electric;
- Engine bypass ratios approaching 20 (or propellers) with small, high-efficiency core engines;
- Higher aspect ratio and laminar flow wings for vehicles cruising at lower speeds and higher altitudes (approximately 40,000–45,000 feet); and
- Energy—conventional/biofuel most prevalent, plus hybrid electric.

Supersonic Aircraft:

- Highly integrated configurations with unique shaping to practically eliminate sonic boom and permit supersonic overland flight; and
- Variable flowpath propulsion systems to maximize cruise efficiency while lowering takeoff and landing noise.

Both Subsonic Fixed Wing and Supersonic Aircraft:

- Broadly applicable, critical technologies including flow control, light weight and higher temperature materials, aeroelastic structures

The results of the Phase I N+3 Concept Studies provide critical data that will guide NASA in future technology investments for technology developments in both green aviation and air transportation systems, and also serve as a basis for Phase II proposals under evaluation. This would greatly enable the assessment and identification of critical needs and requirements (technology portfolio) for technology roadmap developments for potential future commercial aircraft scenarios and advanced vehicle concepts to meet the anticipated national challenges in the N+3 timeframe to achieve performance and environmental goals. The Phase II awards are expected to be made in November 2010.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Complete new suite of integrated multidisciplinary analysis tools to predict noise, NOx, takeoff/landing performance, cruise performance, and Take-Off Gross Weight (TOGW) for conventional ("tube and wing") aircraft and unconventional aircraft (e.g., hybrid wing-body). | None | 8AT07 Green | 9AT7 Green | 10AT07 Green |
| Demonstrate control concepts through flight simulation that would contribute towards development of a flight control optimization tool for variable speed engine and transmission with no negative handling quality effects. | 7AT4 Green | 8AT09 Green | 9AT8 Green | 10AT08 Green |
| Develop computational models to predict integrated inlet and fan performance and operability and compare models to experimental data. | None | 8AT11 Yellow | 9AT9 Green | 10AT09 Green |
| Complete CFD predictions of ramjet-to-scramjet mode-transition and compare to wind tunnel and/or X-51 flight test data. | None | None | 9AT10 Yellow | 10AT10 Yellow |

**Why NASA did not achieve APG 10AT10:** NASA delayed this work into FY 2011 due to Air Force X-51 flight delays. NASA received the data from the first flight on May 26, 2010, in August 2010. The next flight (second of four) is scheduled for the December 2010 through January 2011 time period. The data from the remaining X-51 flights is required to meet APG. The APG completion date estimate has been revised to September 2011.

**Plans for achieving 10AT10:** Information from remaining flights of Air Force X-51 is required to achieve this APG.

This future aircraft design concept for supersonic flight over land dramatically lowers the level of sonic booms through the use of an "inverted-V" engine-under wing configuration. Other revolutionary technologies help achieve range, payload and environmental goals. This concept is one of two designs presented in April 2010 to the NASA Aeronautics Research Mission Directorate for its NASA Research Announcement-funded studies into advanced supersonic cruise aircraft that could enter service in the 2030-2035 timeframe.

Credit: NASA/Lockheed Martin Corporation

## *Outcome 3E.4: Ensure the continuous availability of a portfolio of NASA-owned wind tunnels/ground test facilities, which are strategically important to meeting national aerospace program goals and requirements.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| None | Green | Green | Green |

Credit: NASA

An engineer works with a model of the X-48B in one of NASA's wind tunnels.

**Recovery Act funds working to keeping the Nation's aerospace assets ready**

In FY 2010, NASA's Aeronautics Research Mission Directorate, through the Aeronautics Test Program (ATP), substantially reduced the Agency's deferred maintenance backlog for ground test facilities through an ambitious facility maintenance investment program, funded in part by the American Recovery and Reinvestment Act of 2009 (ARRA). ATP projects are selected on the basis of safety and reliability needs, technical performance and projected test capability requirements; much of which were identified by the 2008 ATP Facility Assessment effort. Overall, ATP investments in the first five years reduced the NASA deferred maintenance backlog for these national assets by more than 20 percent, based on deferred maintenance estimates for NASA wind tunnels in the FY 2006 NASA Deferred Maintenance Assessment Report.

ATP also implemented major capability upgrades with approximately $20 million in funding provided by the ARRA. Together with the above mentioned ARRA investments in major maintenance projects, this initiative represents the largest allocation for national wind tunnel investments in several decades. These investments will provide the testing community with significantly improved acoustic research capability and new engine icing research capability. The investments also provide upgraded data, control, and support process equipment to improve facility reliability and availability to address customer needs.

NASA provides aeronautical test facility access to many national partners. In FY 2010, ATP continued to collaborate with several national organizations to foster effective partnerships and working relationships with national partners including the Department of Defense (DoD) Test Resource Management Center, and the American Institute of Aeronautics and Astronautics U.S. Industry Test Facilities Working Group. ATP also sponsored or co-sponsored several working group meetings to promulgate the National Aeronautics Research and Development Policy.

On July 15, 2010, NASA management participated in the seventh National Partnership for Aeronautical Testing (NPAT) Council meetings convened in Arlington, VA. This meeting continued the exchange of ideas which will focus on strengthening the partnership and establishing a foundation that will lead to a national aeronautics test infrastructure strategy. Other participants included the DoD's director for the Defense Test Resource Management Center and representatives from the separate DoD services.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Achieve test customer evaluation ratings averaging greater than 90% for overall quality and timeliness of ATP facility operations, based on feedback received in post-test customer surveys. | None | None | None | 10AT11 Green |

## *Outcome 3E.5: For vehicle and propulsion technologies that simultaneously reduce fuel burn, noise, and emissions, by 2016 develop a well-informed trade space, document performance potential, and identify technical risks to a level that enables incorporation of the technologies into the design of new aircraft.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| None | None | None | Yellow |

Credit: NASA

A chase plane follows the remotely controlled X-48B as it makes a test flight.

**NASA partners to advance hybrid wing body aircraft technology**

An example of progress toward Outcome 3E.5 was shown during FY 2010, when a multi-government and industry collaboration between NASA, the Air Force Research Laboratory, Boeing, and Cranfield Aerospace, completed the first phase of the X48-B Low Speed Flight Test Program following its 80th test flight on March 19, 2010. All flights were flown at NASA's Dryden Flight Research Center at Edwards, CA.

Researchers conducted the X-48B Phase 1 flight test program in three distinct stages.

In the first stage, researchers flew the aircraft through a variety of maneuvers intended to define the overall flight capabilities away from stall regimes and to discern the general stability and flight handling characteristics of the aircraft.

In the second stage, NASA and its partners performed more aggressive maneuvers to assess the aircraft capabilities under more demanding flight conditions such as stalls, steady heading sideslips and engine-out maneuvers. In this stage, the plane was taken to its limit of controlled flight and successfully recovered.

In the third and final stage, "departure limiter assaults" were performed to challenge the ability of the aircraft's flight control system to prevent entry into uncontrolled flight regimes and to validate the software algorithms employed in the computerized flight control system to prevent such occurrence.

The flight test program of the X48-B, demonstrated the tailless hybrid wing body aircraft design could be safely flown and landed in a variety of flight conditions. Through the X-48B low-speed flight tests and data analysis, NASA sought to:

- Explore the stability and control characteristics of a hybrid wing body class vehicle to better understand the unique flight control issues including basic stability, control authority, control interactions, dynamic characteristics, departure susceptibility, and ground effects.
- Develop and evaluate flight control algorithms with special consideration given to control surface allocation and blending, takeoff and landing characteristics, flying qualities, stall recovery, and departure resistance.
- Evaluate prediction and test methods for hybrid wing body class vehicles by correlating flight measurements with ground-based measurements and predictions.

The aerodynamic database is a principle factor in the fidelity of the simulation models. Therefore, the flight test aerodynamic Parameter Identification (PID) analysis was an essential element of the flight test data analysis effort to validate and update the simulation aerodynamic model. A comprehensive, accurate PID analysis enabled the X-48B Program to meet its flight test data analysis objectives and will enable further development of the hybrid wing body concept.

Researchers used the data obtained from the flight tests to develop accurate aerodynamic and control models and incorporated the models into the control system that ultimately will provide a firm basis for developing a system for a larger-scale hybrid wing body vehicle.

**Why NASA is not on track to achieve Outcome 3E.5 as stated:** In addition conducting research through test flights of a hybrid wing body aircraft configuration, NASA sought out additional advanced vehicle concepts from its stakeholders through a solicitation. NASA significantly re-scoped the effort for the NASA Research Announcement (NRA) mid-year, changing the requirements from an advanced vehicle concept study NRA to an advanced vehicle concept study that will develop two concepts to the Preliminary Design Review (PDR) stage.

**Plans for achieving Outcome 3E.5:** NASA is currently negotiating these contracts and expects to announce awards in the first quarter of FY 2011.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| In FY 2010, award a contract to conduct N+2 vehicle systems studies. | None | None | None | 10AT12 Yellow |

**Why NASA did not achieve APG 10AT12:** NASA significantly re-scoped the effort for the NRA mid-year, changing the requirements from an advanced vehicle concept study NRA to an advanced vehicle concept study that will mature two concepts to PDR stage.

**Plans for achieving 10AT12:** NASA is currently negotiating these contracts and expects to announce awards in the first quarter of FY 2011.

# Sub-Goal 3F

## Understand the effects of the space environment on human performance, and test new technologies and countermeasures for long-duration human space exploration.

| Summary of Ratings for Sub-Goal 3F | |
|---|---|
| 4 Outcomes | 12 APGs |
| Green = 4 | Green = 11 |
| Yellow = 0 | Yellow = 1 |
| Red = 0 | Red = 0 |
| White = 0 | White = 0 |

| FY 2010 Cost of Performance (Dollars in Millions) |
|---|
| $252.0 |

When human explorers journey deeper into space, they will be subjected to the microgravity, radiation, and isolation of space for long periods of time. Keeping crews physically and mentally healthy during long-duration missions requires new technologies and capabilities. Through a combination of ground- and space-based research, NASA is studying how the space environment, close quarters, heavy workloads, and long periods of time away from home contribute to the physical and psychological stresses of space exploration. In addition, NASA is developing innovative methods and technologies that can prevent or mitigate the effects of these stresses and that meet the basic needs of astronauts, oxygen, water, food, and shelter, with systems that can operate dependably for long durations. This work ranges from studies on the risks of space travel to designing guidelines for ensuring astronaut health to creating and testing new life support hardware.

## Benefits

The medical knowledge and diagnostic, preventative, rehabilitative, and treatment technologies NASA uses to keep humans healthy and productive in space can also improve the medical treatment and health of humans on Earth. For example, NASA's research into human adaptation to microgravity has helped scientists better understand the changes that come with aging, such as bone loss, muscle atrophy, and loss of balance.

Other branches of government have benefited from NASA technology sharing and expertise. NASA mobile communications platform designs for future lunar missions led to fleet improvements for tactical robots now being deployed by the U.S. Army. The Multi-function Agile Remote Control Robot (MARCbot) helps soldiers search out and identify improvised explosive devices. Over the years, companies have taken NASA life-support and medical technologies and have developed them into commercial products that serve the public. Light-emitting diodes, originally designed to grow plants in experiments aboard the Space Shuttle, are now used to treat brain tumors. Devices built to measure the astronauts' equilibrium when they return from space are widely used by major medical centers to diagnose and treat patients with head injuries, stroke, chronic dizziness, and central nervous system

Photo previous page: STS-131 and Expedition 23 crew members gather for a group portrait in the Kibo laboratory of the International Space Station while Space Shuttle *Discovery* was docked with the Station. (Credit: NASA)

disorders. A company turned a small, portable device originally designed to warn Space Shuttle and International Space station (ISS) crewmembers of depressurization into a hand-held device that warns pilots, mountain climbers, skydivers, and scuba divers of hazardous conditions before depressurization and hypoxia become a health threat. Another company licensed powerful biosensor technology from NASA to use in its water analyzer, which can alert organizations to potential biological hazards in water used for agriculture, food and beverages, showers, and at beaches and lakes, within hours instead of the days required by conventional laboratory methods.

For more information on NASA technology transfer successes, please visit the Spinoff home page at *http://www.sti.nasa.gov/tto/*.

## Risks to Achieving Sub-Goal 3F

A major challenge in completing all the planned experiments for long-duration space flight is the availability of flight opportunities to conduct research on crew and associated systems.

## NASA in the Spotlight

### *NASA Assists Trapped Chilean Miners*

After learning about the 33 miners trapped in the San Jose copper and gold mine near Copiapo, Chile, NASA experts were eager to offer their assistance. On August 31, a NASA team of experts arrived in Santiago as part of NASA's commitment to provide U.S assistance. As experts on working and living in small, dark, and isolated places, NASA offered advice on medical, nutritional, and behavioral health issues. The NASA team also provided suggestions regarding the rescue cages that were specially-designed to pull the trapped miners out of the shaft that was dug over 2,000 feet into the ground. The NASA team included two medical doctors, a psychologist, and an engineer experienced in training and planning for emergencies in human spaceflight and its protection of humans in the hostile environment of space. The NASA team urged the miners to regulate their sleep patterns and to start an exercise regime as soon as their nutrition improved.

All the miners emerged safely from the 2,300-foot escape shaft on October 13, 2010.

For more on this story go to h*ttp://www.nasa.gov/news/chile_assistance.html*.

Photo above: NASA Engineering and Safety Center Principal Engineer Clint Cragg consults with Rene Aguilar, deputy chief of rescue operations for the Chilean mine disaster. (Credit: C. Penafiel, U.S. Embassy in Chile)

## *Outcome 3F.1: By 2016, develop and test candidate countermeasures to ensure the health of humans traveling in space.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Yellow | Green |

### Improving ISS medical support systems

In FY 2010, NASA worked to enable long-duration human space missions by continuing efforts to understand and lessen the harmful effects of the space environment on humans and to develop new technologies that reduce mission resource requirements. Under the IntraVenous fluid GENeration (IVGEN) project, NASA developed a device to generate United States Pharmacopeia (USP) grade IV fluid in the microgravity environment on the ISS using materials already available on the ISS. Due to the large mass and volume and a finite shelf life of water, this new filtration system will save significant resources by generating IV fluids when needed. The hardware was launched to ISS in March 2010, and has been successfully integrated into the Multi-Purpose Logistics Module, where it has been operated to produce medical grade water. This device gives flight surgeons more options in treating ill crew members.

### Reducing cancer risks for astronauts

Exposure to the radiation generated by solar particle events and galactic cosmic rays poses cancer risks to astronauts. To combat this problem, NASA developed a cancer risk projection code and evaluated uncertainties in factors that enter into the model. The NASA Cancer Risk Model will help predict an astronaut's chance of developing cancer. NASA also developed the Space Cancer Risk Model Graphical User Interface which integrates various components in the cancer risk projections in order to apply them to human space situations. NASA plans to use these tools for ISS missions and for future exploration missions to the Moon, asteroids, or Mars.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Deliver a Human Interface Design Handbook for use in designing exploration vehicles. | None | None | None | 10AC04 Green |
| Deliver and publish an initial version of the acute radiation risk projection model for lunar missions. | None | None | None | 10AC05 Green |
| Deliver a device for launch to ISS to test the technology of producing medical grade water on a spacecraft. | None | None | 9AC7 Yellow | 10AC06 Green |
| Complete the assessment study of a capability to test bone and muscle countermeasures in simulated lunar gravity. | None | None | None | 10AC07 Green |
| Complete the 2010 quantitative assessment of the uncertainties in cancer risk projections for space radiation exposures in support of lunar exploration missions. | None | None | None | 10AC08 Green |

# *Outcome 3F.2: By 2012, identify and test technologies to reduce total mission resource requirements for life support systems.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |

Credit: NASA

Astronaut Tracy Caldwell (right), flight engineer for Expeditions 23 and 24, participates in an Environmental Control and Life Support System (ECLSS) training session with instructor Cindy Koester. The ECLSS, which is onboard the ISS, includes systems for reclaiming water and generating oxygen. NASA is using the ISS as a test bed for technologies that will enable future long-duration human space missions.

### Developing technologies for future lunar missions

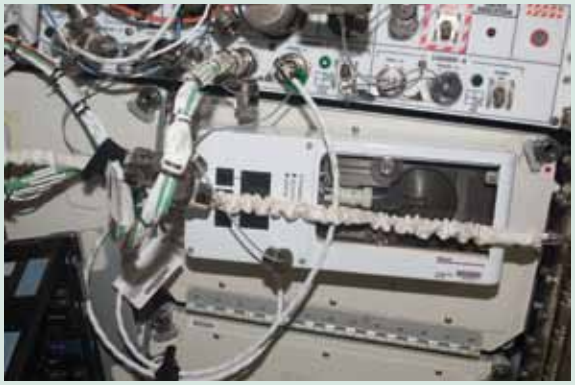
Long-duration human space missions require life support systems that are efficient, reliable, compact, and which use minimal amounts of consumables. In order to support increases in mission duration, NASA carries out research to improve techniques for atmosphere management and for recycling the air to reduce the consumables associated with providing a breathable atmosphere, both of which are essential to maintaining a safe environment for human beings to live.

In support of a long-term strategy to develop air "recycling" technologies for future, long-term Moon missions, NASA conducted a trade study to evaluate candidate technologies for carbon dioxide reduction. This research included an analysis of currently available carbon dioxide reduction subsystem technologies and the consumables necessary for each system for one-, five- and 10-year missions. Based on these analyses, researchers provided conclusions and recommendations regarding which technologies should be developed into flight hardware.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| As part of technology development for closed-loop air revitalization for lunar surface habitats, conduct a trade study to evaluate candidate technologies for carbon dioxide reduction in support of down selection for development of a breadboard unit. | None | None | None | 10AC09 Green |

## *Outcome 3F.3: By 2012, develop reliable spacecraft technologies for advanced environmental monitoring and control and fire safety.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |



Credit: NASA

The ENose is shown installed in the U.S. Destiny Laboratory onboard the ISS.

### A breath of fresh air in space

NASA monitors the interior of spacecraft to ensure that the safety of astronaut living quarters and the optimal functionality of the life support and habitation systems. Internal atmosphere monitoring works to detect any unusual events that may be caused by chemical spills or malfunctioning systems but can also track the functioning and efficiency of atmosphere management systems.

In April 2010, NASA launched the Vehicle Cabin Atmosphere Monitor (VCAM), an instrument that identifies minute quantities of gases inside the ISS that could harm the crew's health. The VCAM operates autonomously and maintenance free, approximately once per day, with a self-contained gas supply sufficient for a one-year lifetime. If successful, instruments like VCAM could accompany crewmembers during long-duration exploration missions.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Demonstrate six months of experimental operation of the Electronic Nose (ENose) on orbit. | None | None | None | 10AC11 Green |
| Demonstrate one year of experimental operation of the Vehicle Cabin Atmosphere Monitoring (VCAM) system on orbit. | None | None | None | 10AC12 Yellow |

**Why NASA did not achieve APG 10AC12:** NASA delivered and installed the VCAM in FY 2010. To date, the instrument has operated successfully; however, due to delays in the Space Shuttle launch schedule this instrument was not in place in time to demonstrate a full year of operation by the close of the fiscal year, per the annual performance goal.

**Plans for achieving 10AC12:** The VCAM is fully functional and on track for reaching one year of experimental operation in March 2011.

## *Outcome 3F.4: By 2012, identify and develop tools, methods, and technologies for assessing, improving and maintaining the overall health of the astronaut corps, for mission lengths up to 180 days in microgravity or 1/6 G.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| None | None | Green | Green |

**NASA launches new systems to support astronaut health**

In FY 2010, NASA developed an initial set of clinical practice guidelines for astronaut care in the following areas: onychomycosis (toe fungus), hypertension, hyperlipidemia (cholesterol), renal stones, and sleeping disorders. NASA also adopted the U.S. Preventive Services Task Force recommendations for preventive health screening and modified them to include additional occupational screenings for specific risks associated with space flight such as radiation exposure, microgravity and other environmental stressors.

NASA also replaced the Longitudinal Study of Astronaut Health with a new program, the Lifetime Surveillance of Astronaut Health (LSAH). The new LSAH began in the summer of 2010 and will screen and monitor astronauts for occupationally-related disease. This will allow for a systematic evaluation of astronauts to detect potential health problems at an early state and to facilitate action to prevent the development or progression of occupationally related diseases.

In FY 2010, NASA also launched a data management infrastructure to hold astronaut medical data. This multi-database system captures clinical data collected pre- and post-flight for all astronauts, some in flight data, and flight surgeon notes about missions as well as the reports generated by laboratories for various medical requirements. In populating that data management system, priority was given to current missions, and work is ongoing to enter the past mission data.

One of the most significant efforts in the use of tools, methods, and technologies for assessing, improving and maintaining the overall health of astronauts was applied toward the use of ultrasound on ISS. Ultrasound is the only imaging technology available in flight. In order to understand what is seen in flight, similar data must be available from pre-flight uses on the ground. This concept of operations has been implemented through the installation of ultrasound in the Johnson Space Center clinics and ongoing work to explore the usefulness of ultrasound for monitoring and diagnosing conditions. Furthermore, techniques for remote guidance of ultrasound sessions for use with non-clinician operators have been developed and these techniques have been shown to produce clinically useful data from sessions with non-clinician operators.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Capture 43% of current and former astronaut medical requirements data in a comprehensive medical data management infrastructure. | None | None | 9SFS2 Green | 10SFS01 Green |
| Create a set of clinical practice guidelines for monitoring known risks associated with space flight. | None | None | None | 10SFS02 Green |
| Capture 100% of medical and environmental data required by Medical Operations in a form capable of queries. | None | None | 9SFS3 Yellow | 10SFS03 Green |
| Create an integrated concept of operations to use ultrasound for ground-based clinical care as a test bed for in flight uses. | None | None | None | 10SFS04 Green |

# Strategic Goal 4

## Bring a new Crew Exploration Vehicle into service as soon as possible after Shuttle retirement.

| Summary of Ratings for Strategic Goal 4 | |
|---|---|
| 1 Outcome | 5 APGs |
| Green = 0 | Green = 4 |
| Yellow = 0 | Yellow = 0 |
| Red = 0 | Red = 0 |
| White = 1 | White = 1 |

| FY 2010 Cost of Performance (Dollars in Millions) |
|---|
| $4,377.8 |

Strategic Goal 4 was originally set as a key component in supporting NASA's Mission. The Nation's current space transportation system, the Space Shuttle, is not designed for human exploration beyond low Earth orbit.

To achieve the long-term objective of returning explorers to the Moon and eventually sending them to Mars, NASA initiated the Constellation Program. The program has been responsible for projects focused on designing, building, and testing the Orion Crew Exploration Vehicle, the expendable crew launch vehicle Ares I, the heavy-lift cargo launch vehicle Ares V, and spacesuits and tools required by the flight crews.

In addition, projects under this Strategic Goal have focused on creating or transitioning associated ground and mission operations infrastructure from the Space Shuttle Program to supporting low Earth orbit missions. Orion was originally designed to be America's new spacecraft for human space exploration, capable of carrying four crewmembers to the Moon and serving as the primary vehicle for future missions transporting crew and cargo to and from the International Space Station. The Ares I design consisted of a solid rocket booster and an upper stage capable of launching Orion into low Earth orbit. In FY 2010, activities under this Strategic Goal have been delayed or shifted to reflect new Presidential and Congressional direction in NASA's space exploration goals.

# Benefits

If completed, Orion would have supported the expansion of human exploration missions and provided the means to take humans to the Moon to conduct scientific activities and make discoveries that cannot be achieved solely with robotic explorers. Although NASA's goals relating to this program have changed, NASA is optimistic that many capabilities developed by the Constellation Program will feed forward into new programs. For example, NASA is exploring options to use the Orion capsule for autonomous rendezvous and docking. Work carried out in the areas of advanced robotics, propulsion development and testing, friction stir welding, autonomous landing and hazard avoidance, and entry, descent, and landing technologies will enable further advancement in the new initiative areas directed by Congress and the President.

NASA's efforts to develop Orion and the Ares launchers have accelerated the development of technologies that are important for the economy and national security. The advanced systems and capabilities required for space travel include power generation and storage, communications and navigation, networking, robotics, and improved materials, all of which could be used on Earth to meet commercial and other national needs.

Photo above: NASA Dryden visual communications manager Steve Lighthill carefully smoothes out a NASA logo decal after affixing it to the Orion test module that will be flown in the Launch Abort System flight tests. (Credit: NASA/T. Landis)

# Risks to Achieving Strategic Goal 4

In the FY 2011 budget process, the President proposed to Congress that the Constellation Program be transitioned to a new set of programs and NASA adjusted its spending on the program consistent with its budget request and with the Appropriation provided by Congress for FY 2010. NASA has continued its work on Constellation but reductions in planned work content were made to ensure availability of funds required to complete work already under contract. These reductions have made it difficult for NASA to achieve some of the Constellation Program-related goals and outcomes planned for FY 2010. While NASA determines how to best transition the Constellation Program, consistent with the NASA Authorization Act of 2010 and its FY 2011 Appropriations Act when final, NASA remains poised to leverage Constellation assets to contribute to future exploration beyond low Earth orbit.

(Right) On May 27, 2010, a weld technician looks on as the bulkhead and nosecone of the Orion spacecraft are joined using friction stir welding at NASA's Michoud Assembly Facility in New Orleans. The vehicle was inverted in the tool for this weld.

(Above) Another weld technician monitors as the Universal Weld System completes the final friction stir weld on the Orion spacecraft.

Nondestructive evaluations will validate the strength and integrity of the weld before the spacecraft is prepped for ground testing in flight-like environments, including static vibration, acoustics, and water landing tests.

(Credit, both: NASA)

## *Outcome 4.1: No later than 2015, transport three crewmembers to the International Space Station and return them safely to Earth,demonstrating an operational capability to support human exploration missions.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Yellow | Yellow | Yellow | White |

Credit: NASA

The Crew Module lands successfully after the Pad Abort-1 test on May 6, 2010, at White Sands Missile Range in New Mexico. Three main parachutes lowered the Crew Module to the ground.

The Constellation Program performed significant and successful flight demonstrations in FY 2010, including the Ares 1-X Launch (see the Strategic Goal 4 highlight in *Performance Results* for more information), the Ares I First Stage Development Motor Test firing, and the Pad Abort-1 test for the Orion Crew Exploration Vehicle.

**Why NASA rated Outcome 4.1 White:** In the FY 2011 budget process, the President proposed to Congress that the Constellation Program be transitioned to a new set of programs, and NASA adjusted its spending on the program consistent with its budget request and with the Appropriation provided by Congress for FY 2010. NASA has continued its work on Constellation, but reductions in planned work content were made to ensure availability of funds required to complete work already under contract. These reductions have made it difficult for NASA to achieve some of the Constellation Program-related goals and outcomes planned for FY 2010. While NASA determines how to best transition the Constellation Program, consistent with the NASA Authorization Act of 2010 and its FY 2011 Appropriations Act when final, NASA remains poised to leverage Constellation assets to contribute to future exploration beyond low Earth orbit.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Complete Pad Abort-1 test for the Orion Crew Exploration Vehicle. | None | None | 9CS6 Yellow | 10CS01 Green |
| Complete the integrated Preliminary Design Review (PDR) for the Constellation Program. | None | 8CS14 White | 9CS12 Yellow | 10CS02 White |
| Complete Ares 1 First Stage Development Motor (DM-2) test firing. | None | None | None | 10CS03 Green |
| Complete the Preliminary Design Review (PDR) for the Ground Operations (GO) Project. | None | 8CS04 White | 9CS3 Yellow | 10CS05 Green |
| Complete the Preliminary Design Review (PDR) for the Mission Operations (MO) Project. | None | 8CS11 Yellow | 9CS4 Yellow | 10CS06 Green |

**Why NASA rated 10CS02 White:** In the FY 2011 budget process, the President proposed to Congress that the Constellation Program be transitioned to a new set of programs, and NASA adjusted its spending on the program consistent with its budget request and with the Appropriation provided by Congress for FY 2010. NASA has continued its work on Constellation, but reductions in planned work content were made to ensure availability of funds required to complete work already under contract. These reductions have made it difficult for NASA to achieve some of the Constellation Program-related goals and outcomes planned for FY 2010. While NASA determines how to best transition the Constellation Program, consistent with the NASA Authorization Act of 2010 and its FY 2011 Appropriations Act when final, NASA remains poised to leverage Constellation assets to contribute to future exploration beyond low Earth orbit.

# Strategic Goal 5

## Encourage the pursuit of appropriate partnerships with the emerging commercial space sector.

| Summary of Ratings for Strategic Goal 5 | |
|---|---|
| 3 Outcomes | 10 APGs |
| Green = 2 | Green = 8 |
| Yellow = 1 | Yellow = 2 |
| Red = 0 | Red = 0 |
| White = 0 | White = 0 |

| FY 2010 Cost of Performance (Dollars in Millions) |
|---|
| $189.7 |

Through Strategic Goal 5, NASA primarily seeks to support new launch services and technologies that will enable future robotic and human missions. Many of NASA's robotic missions are already launched on commercial vehicles, and as the Space Shuttle nears retirement, NASA is pursuing International Space Station (ISS) crew and cargo delivery and return services provided by U.S. launch service companies.

Also in line with this Strategic Goal, the Agency partners with industry and academia to leverage outside investments and expertise while providing an economic incentive to invest in NASA programs. The Innovative Partnerships Program (IPP) consists of three elements: Technology Infusion, Innovation Incubation, and Partnership Development. Together, these program elements serve to increase the range of technology solutions for NASA, enable cost savings, and accelerate technology maturation. All of IPP's functions primarily serve NASA's mission interests, both near- and long-term, and with respect to a broad range of technologies and technology readiness. IPP targets a broad spectrum of U.S. industrial and non-profit entities and provides them the opportunity for grass-roots direct involvement in NASA's exploration and other missions.

NASA's Commercial Crew and Cargo Program applied $50 million in American Recovery and Reinvestment Act (ARRA) funds to stimulate efforts within the private sector to develop and demonstrate human spaceflight capabilities in an effort is known as Commercial Crew Development (CCDev). These efforts are fostering entrepreneurial activities leading to job growth in engineering, analysis, design, and research and are supporting the creation of new markets.

## Benefits

Since NASA's creation in 1958, the commercial sector has been an important Agency partner in space exploration. NASA purchases launch services for robotic missions from the commercial space sector. NASA also works with commercial partners to develop communication and navigation systems, build spacecraft, and design spacesuits. Along the way, the commercial space sector has grown into a multi-billion dollar industry that delivers numerous services, such as satellite television and global navigation, to the public and contributes to a strong U.S. economy.

Photo above: The United Launch Alliance Atlas V rocket carrying NASA's Solar Dynamics Observatory heads into the "wild blue yonder" from Launch Complex 41 an Cape Canaveral Air Force Station on February 11, 2010. The Atlas V is one of the commercial medium-heavy lift expendable launch vehicles available to NASA for launching robotic missions. NASA is working with commercial launch providers to expand the selection of available vehicles, particularly in the small and medium class. (Credit: S. Joseph and T. Gray)

Historically, several large corporations have dominated the commercial space industry, but now start-up ventures are pushing the industry into new areas. The Commercial Orbital Transportation Services (COTS) Program supports aerospace companies to demonstrate orbital cargo transportation services, and is designed to encourage the emerging industry. By helping emerging companies expand their services and increase their experience, NASA supports the growth of a competitive market and provides NASA with access to new capabilities.

Advancing technology through partnerships has always been important to NASA, not only to address NASA's needs, but also to apply NASA-derived technology to a range of applications that provide broad benefit to the public. IPP provides the technology solutions for NASA programs and projects through dual-use technology development and joint-partnerships. By broadening NASA's connection to emerging technologies, IPP provides an increased range of technological solutions for programs while reducing costs. IPP provides technology transfer out of NASA (called spinoffs) for commercial or socio-economic benefit to the Nation. In addition, IPP facilitates protection of the government's rights in NASA's inventions, as mandated by legislation. NASA's Technology Transfer, Small Business Innovative Research (SBIR), and Centennial Challenges tap into sources of innovation outside NASA and leverage NASA's resources with private or other external resources to develop new technologies for NASA mission use. IPP also transfers technologies having strong potential for commercial applications yielding public benefits.

# Risks to Achieving Strategic Goal 5

Using new launch systems presents potential increased risk to the Agency because the companies' launch systems are unproven. NASA needs to balance the need to encourage emerging companies against the need to carry out Agency missions with limited risk. The successful implementation of commercial services involves detailed technical work needed to successfully integrate private sector vehicles and NASA systems. With funded and unfunded partners onboard for the COTS project, NASA and its partners are working closely to ensure that launch services to the ISS, communications, docking or berthing, operational, and navigational interfaces are well planned and that the technical requirements well understood. In addition, the commercial partner services must prove, through the ISS safety panel process, that their system is sufficiently safe to be allowed to approach the Station.

NASA faces issues with all classes of launch services. Small class launch services market is experiencing an increase in the available launchers but a limited supply of payloads. This limited market may make it difficult to sustain multiple suppliers and desired competition. Although there are no immediate replacements for medium-class launch services for NASA's robotic missions, the SpaceX Falcon 9 has experienced a successful launch and NASA continues to work with SpaceX and other emerging providers to help meet NASA's current and future launch services requirements.

## *Outcome 5.1: Develop and demonstrate a means for NASA to purchase launch services from emerging launch providers.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |

Credit: NASA

An Aerojet AJ26 rocket engine was delivered to NASA's Stennis Space Center on July 15, 2010. This is the first of a series of Taurus II engines to be tested at Stennis to include acceptance testing of flight engines. Stennis will provide propulsion system acceptance testing for the Taurus II space launch vehicle, which is being developed by Orbital Sciences Corporation. The first Taurus II mission will be flown in support of NASA's Commercial Orbital Transportation Services cargo demonstration to the International Space Station.

### NASA partners with emerging launch providers

The Launch Services Program (LSP) completed a major procurement by awarding the NASA Launch Services (NLS) II Contracts in September 2010. These contracts brought several new launch vehicles closer to reality, opening the door for additional competition in the small to small/medium class range of launch services.

To encourage and provide assistance to emerging launch providers, NASA's LSP participated in a series of technical interchange meetings with emerging providers Space Exploration Technologies (SpaceX) regarding the Falcon 1 and 9 launch vehicles, and with Orbital Sciences Corporation regarding the Taurus II launch vehicle. NASA's LSP also worked with SpaceX to assess Falcon 1 performance and provide feedback on trajectory modeling and performance and assessed the successful Falcon 9 maiden flight. As with other providers contributing to NLS contract, the Agency established an LSP resident office in the summer of 2010 at SpaceX's design and manufacturing facility in Hawthorne, California, to enhance communications between the organizations.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| The Launch Service Program will capture 100% of significant technical interchange information with emerging launch providers as provided under existing contract mechanisms. The Engineering Review Board Information System (ERBIS) will be used to capture specific technical recommendations and opportunities for risk reduction. | 7SFS4 Green | 8SFS01 Green | 9SFS5 Green | 10SFS05 Green |

## *Outcome 5.2: By 2010, demonstrate one or more commercial space capabilities for ISS cargo and/or crew transport.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Yellow |

Credit: SpaceX

NASA astronauts Cady Coleman and Scott Kelly discuss spacecraft cargo operations with SpaceX engineers as part of training with SpaceX's Dragon spacecraft. The Dragon is part of the company's launch vehicle/spacecraft system being developed under COTS.

**NASA partners complete milestones**

NASA's Commercial Orbital Transportation Services (COTS) project is an investment designed to spur development of a cost-effective, U.S. commercial capability to carry cargo to the ISS, with future options for transporting crew. The COTS project currently funds Space Act Agreements (SAAs) with two partners, Space Exploration Technologies Corporation (SpaceX) and Orbital Sciences Corporation (Orbital).

Throughout FY 2010, SpaceX and Orbital continued to make progress towards Outcome 5.2 by completing several agreed upon milestones. SpaceX completed two key milestones in FY 2010. In December 2009, SpaceX completed a cargo demonstration using a sample manifest that included physical stowage of cargo simulators in spacecraft and trunk, power and data to sample cargo, and verification procedures in preparation for the flight demonstrations. Additionally, SpaceX successfully completed the first Demonstration Readiness Review in preparation for its first COTS mission scheduled for early FY 2011.

Orbital successfully completed three key milestones in FY 2010. In November 2009, Orbital completed the ISS phase 2 safety review in accordance with the Space Station safety review process. Orbital completed their COTS system Critical Design Review (CDR), demonstrating completion of the design phase in March 2010, and in August 2010, completed assembly of the Service Module structure in preparation for structure testing.

**Why NASA is not on track to achieve Outcome 5.2:** Both partners, Space Exploration Technologies Corporation (SpaceX) and Orbital Sciences Corporation (Orbital), are making progress in demonstrating their respective transportation capabilities. The partners moved their initial demonstration flights to FY 2011 due to technical issues encountered during development efforts.

**Plans for achieving Outcome 5.2:** SpaceX is planning for its first ISS demonstration flight in late fall 2010 with remaining flights scheduled for later in FY 2011. Orbital currently is planning its ISS demonstration flight for fall 2011.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| In FY 2010, have at least one partner demonstrate flight proximity operations with ISS. | None | 8CS08<br>Yellow | 9CS9<br>Yellow | 10CS07<br>Yellow |
| By the end of FY 2010, conduct one or more demonstration flights to, and berth with, the ISS. | None | None | None | 10CS08<br>Yellow |

**Why NASA did not achieve APG 10CS07:** Both partners, SpaceX and Orbital, made progress in demonstrating their respective transportation capabilities. The partners moved their initial demonstration flights to FY 2011 due to technical issues encountered during development efforts and are continuing toward demonstrating flight operations with ISS in FY 2011.

**Plans for achieving 10CS07**: The second SpaceX flight, in June 2011, will demonstrate flight proximity operations with ISS. Orbital currently anticipates scheduling its demonstration flight for FY 2012.

**Why NASA did not achieve APG 10CS08:** Both partners, SpaceX and Orbital, made progress in demonstrating their respective transportation capabilities. The partners moved their initial demonstration flights to FY 2011 due to technical issues encountered during development efforts and are continuing toward demonstration flights to, and berthing with, ISS in FY 2011.

**Plans for achieving 10CS08:** SpaceX is planning for its third demonstration flight to, and berth with, ISS in late FY 2011. Orbital currently anticipates scheduling its demonstration flight for FY 2012.

## NASA in the Spotlight

### *Taking the "Search" out of Search and Rescue*

Their emergencies happened hundreds, if not thousands, of miles from one another, but the captain whose vessel had become disabled near Kamalino, Hawaii, the pilot who crashed onto the Knik Glacier near Anchorage, Alaska, and the hiker who suffered a compound fracture while hiking near Merritt, Washington, all share a common experience: They were plucked to safety in the weeks leading up to the Labor Day 2010 weekend due to NASA technology.

In the 30 years since it began operations, the international Search and Rescue Satellite-Aided Tracking (SARSAT) program has saved more than 28,000 lives worldwide. Although this technology has helped save thousands of lives, perhaps the one rescue that most clearly demonstrates the value of the space-based search and rescue system is the one involving 16-year-old Abby Sunderland, who was saved in June after floating helplessly in the Indian Ocean about 2,000 miles from Madagascar after a violent storm had damaged her 40-foot vessel, *Wild Eyes*.

In the ultimate display of NASA spin-off technology, Abby's life was changed with a small yellow device, the MicroPLB Type GXL developed under a NASA Small Business Innovation Research (SBIR) program award to Microwave Monolithics Inc. NASA had provided Microwave Monolithics with the specifications to design the beacon, which relayed her distress signal to a SARSAT satellite.

Engineers at NASA's Goddard Space Flight Center, along with NOAA, the Coast Guard, and the Air Force, are developing a new search and rescue system that will detect and locate distress signals from beacons in less than five minutes. The current system, which places repeaters on weather satellites, can actually take up to an hour or more to locate the distress signal depending on the position of the satellite. The Distress Alerting Satellite System will be more efficient because the repeater technology will be placed on the Air Force's 24 Global Positioning System (GPS), instead of NOAA weather satellites.

For more on this technology transfer story go to *http://www.nasa.gov/centers/goddard/news/features/2010/search-and-rescue.html*.

Photo above: Abby Sunderland waves from her vessel, *Wild Eyes*, during her attempt to be the youngest person to sail solo around the world. (Credit: GizaraArts.com)

## *Outcome 5.3: Promote and develop innovative technology partnerships among NASA, U.S. industry, and other sectors for the benefit of Agency programs and projects.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | None | Green |

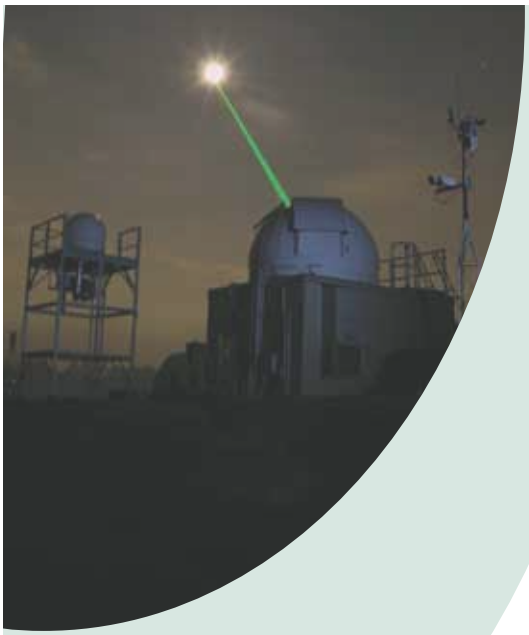
The purpose of this Outcome is to add value to Mission Directorate programs and projects through joint technology development/maturation, at less cost, through partnerships and resulting infusion targeted on Mission Directorate technology gaps to meet mission needs. In addition, Outcome objectives include facilitating the transfer of inventions and technologies to which NASA has title for commercial application and for other public benefits; and infusing commercial applications, or adaptations thereof, thereby incorporating NASA's own technologies back into NASA's missions. Strategies include engaging Mission Directorates at Headquarters and Centers, reaching out to external sectors, and increasing participation from new sources of innovation to address NASA's technology challenges. IPP's role may reasonably be characterized as a facilitator and catalyst in achieving these objectives.

During FY 2010 the inventions of NASA civil servants that IPP had previously reported via its Web-based New Technology Reporting (NTR) tool were recognized by entities like the *Wall Street Journal*, *R&D Magazine*, the Federal Laboratory Consortium, and the Northeast Ohio Technology Coalition. IPP reported on 47 new and significant successful transfers of NASA technologies in the 2010 edition of *Spinoff* magazine.

During the year at least 68 technologies were infused into various NASA programs from IPP's technology investment portfolio. Infused technologies from non-NASA entities and commercial firms fly on NASA missions during the year, are adopted for use in future missions, are chosen for further development after emerging from the IPP portfolio, or otherwise participate meaningfully in NASA's projects and activities. The NASA investment portfolio spans the range of initiatives sponsored by IPP's SBIR/STTR, Seed Fund, Centennial Challenges, FAST, and partnership program elements; together the portfolio provides a constellation of opportunities for non-NASA entities and commercial firms to participate in NASA's ongoing mission. The most significant component of the portfolio, measured in dollar terms, is the assortment of contracts and awards sponsored by the SBIR/STTR program; the FY 2010 edition of *Spinoff* magazine documented approximately 50 new commercialization successes sponsored through SBIR/STTR.

*Spinoff* is available online at *http://www.sti.nasa.gov/tto/*.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Document 40 notable technology transfer successes in NASA's Spinoff publication. | None | None | None | 10IPP01 Green |
| Produce 1100 New Technology Reports (NTRs) produced, representing the new technologies available for potential transfer. | None | None | None | 10IPP02 Green |
| Ratio of total number of licenses generated from the Intellectual Property (IP) portfolio of patents from the last five years relative to the number of patents in that portfolio is equivalent to 40%. | None | None | None | 10IPP03 Green |
| Initiate or expand 29 SBIR/STTR Phase III contracts. | None | None | None | 10IPP04 Green |
| Achieve 175 technology readiness level (TRL) advancements from the Innovative Partnerships Program portfolio of technology development. | None | None | None | 10IPP05 Green |
| Infuse 68 technologies into NASA programs/projects from total Innovative Partnerships Program portfolio. | None | None | 9IPP4 Green | 10IPP06 Green |
| Ratio of SBIR/STTR technologies successfully infused into NASA programs/projects relative to the prior five years of SBIR/STTR Phase II contracts issued is equivalent to 21%. | None | None | None | 10IPP07 Green |



# Strategic Goal 6

## Establish a lunar return program having the maximum possible utility for later missions to Mars and other destinations.

| Summary of Ratings for Strategic Goal 6 | |
|---|---|
| 4 Outcomes | 12 APGs |
| Green = 2 | Green = 11 |
| Yellow = 0 | Yellow = 0 |
| Red = 0 | Red = 0 |
| White = 2 | White = 1 |

| FY 2010 Cost of Performance (Dollars in Millions) |
|---|
| $560.9 |

NASA laid the foundation for the lunar return program by focusing Agency research on robotic reconnaissance explorers, surface nuclear power systems, and advanced communications systems. NASA has conducted extensive research and leveraged partnerships with industry and the international space community to acquire next-generation technologies for life support, communications and navigation, radiation shielding, power generation and storage, propulsion, and resource extraction and processing.

In FY 2010, activities under this Strategic Goal have been delayed or shifted to reflect new Presidential and Congressional direction in NASA's space exploration goals.

# Benefits

NASA and the Agency's partners transfer advanced space exploration systems and capabilities, power generation, communications, computing, robotics, and improved materials from space exploration research and execution, to the commercial sector to serve public, national, and global needs. In the past, technologies developed for space exploration have yielded ground-based applications, such as non-polluting solar energy systems, advanced batteries for laptop computers and cell phones, and fuel cells for electric vehicles.

The activities under Strategic Goal 6 lay the groundwork for NASA's future human space exploration goals. Even as goals shift, the capabilities and knowledge developed under this Strategic Goal will feed forward into new areas of focus and will continue to benefit other efforts across NASA. New power generation and nuclear technologies will help future space exploration missions while autonomous systems and integrated systems health management support safer and more efficient air travel.

# Risks to Achieving Strategic Goal 6

Many of the new, advanced technologies required for NASA's robotic and human exploration missions are either in formulation or the early stages of development. As such, they are subject to challenges that affect any project in its early stages including: reductions in planned budget may prevent technologies from being matured in time to support preliminary design of flight systems; the evolving lunar program architecture may cause technology development priorities to change; and technologies may be more difficult to develop to the required level of maturity than originally anticipated.

Photo above: The Goddard Flight Research Center's Laser Ranging Facility directs a laser (green beam) toward the Lunar Reconnaissance Orbiter (LRO) spacecraft in orbit around the Moon (white disk). The Moon has been over-exposed to show the laser. Researchers are using ranging information from LRO, as well as lunar laser ranging data from other U.S. and international missions, to determine the orientation and orbit of the Moon and to establish highly precise latitude and longitude coordinate frames. This is valuable information when planning either robotic or human lunar exploration missions. (Credit: NASA/T. Zagwodzki)

# *Outcome 6.1: By 2012, complete the transition of applicable Shuttle components, infrastructure, and workforce to the Constellation Systems program.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Yellow | Green | White |

**NASA alters transition strategy**

Due to the Shuttle Manifest extension (announced November 2009), the FY 2011 President's Budget Release (February 2010), which requested the Constellation Program transition, and the creation of the Mission Support Directorate, NASA altered its strategy for ensuring the most efficient and comprehensive transition of applicable Shuttle components, infrastructure, and workforce. This aggressive campaign captures institutional requirements (including infrastructure and workforce) and will be managed at an Agency-level. This larger scope will provide better and more accessible data that can be used to make informed decisions across the Agency rather than at a program-specific level.

**Why NASA rated Outcome 6.1 White:** In the FY 2011 budget process, the President proposed to Congress that the Constellation Program be transitioned to a new set of programs, and NASA adjusted its spending on the program consistent with its budget request and with the Appropriation provided by Congress for FY 2010. The proposed changes to the human spaceflight program in FY 2011 had an impact on civil service and contractor workforce planning. While NASA is not planning reductions to the civil service workforce, the nature of the work done by the civil service workforce would change under the President's FY 2011 budget plan. NASA has also made preliminary program assignments across the Centers for new or extended activities proposed in the FY 2011 budget, helping to clarify the work opportunities for contractors under the proposed portfolio and preparing NASA to execute the work content.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Complete the Exploration Requirements for Institutional Capabilities (ERIC) database update and develop a coordinated final SOMD/ESMD report that incorporates the ERIC update with the Space Shuttle Program's final assessment of real property. | None | 8CS07 Green | 9CS8 Green | 10CS09 Green |
| Complete the Constellation Assessment of Personal Property (CAPP) for Space Shuttle Program property. | None | 8CS07 Green | 9CS8 Green | 10CS10 Green |
| With the Space Shuttle Program, complete and deliver 2 Agency workforce transition strategy report updates to Congress. | None | 8CS07 Green | 9CS8 Green | 10CS11 Green |

## *Outcome 6.2: By 2016, develop and test technologies for in situ resource utilization, power generation, and autonomous systems that reduce consumables launched from Earth and moderate mission risk.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |

Credit: NASA/T. Landis

An S-64 heavy-lift helicopter operated by Erickson Air-Crane carries the ALHAT lidar equipment during a July 2010 flight test at NASA's Dryden Flight Research Center. The helicopter carrying the ALHAT lidar equipment flew over a varied obstacle course set up on Rogers Dry Lake to test the sensor's ability to distinguish the various materials, sizes, shapes, and colors while providing precision vehicle velocity and position. The sensor is being developed to help assure safe landings of future manned and robotic spacecraft on extraterrestrial bodies.

### NASA tests hazard avoidance system

In FY 2010, NASA made significant progress towards demonstrating an autonomous hazard avoidance system for the Altair lunar lander.

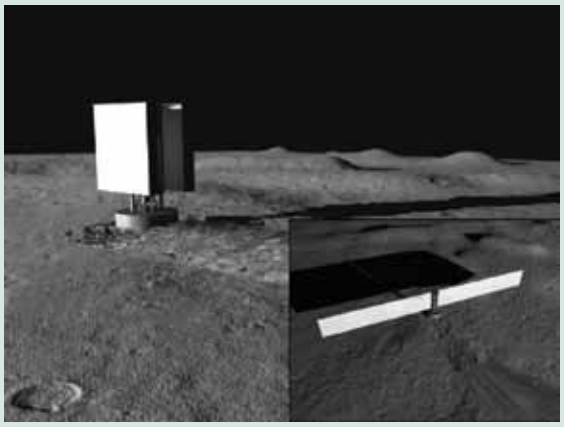
Future missions will need to land near specific resources that are located in potentially hazardous terrain. This capability will be possible when landers are equipped with the ability to automatically recognize the location of the desired landing site while detecting landing hazards during the final descent to the surface. Two critical technologies that must be developed to enable this capability are an active sensor for measuring the topography of the landing site and terrain analysis algorithms.

To prove that these technologies are ready for flight, they must be tested using both field tests and high fidelity simulations. The Autonomous Landing and Hazard Avoidance Technology (ALHAT) field test was conducted in July 2010 at NASA's Dryden Flight Research Center using an Erickson Air-Crane helicopter. This test was designed to integrate the ALHAT navigation system with a flash lidar on a gimbal with real-time sensor control and data collection software.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Demonstrate autonomous hazard avoidance system for Altair lunar lander in helicopter flight test. | None | None | None | 10AC13 Green |

## *Outcome 6.3: By 2013, sufficiently develop and test technologies for nuclear power systems to enable an informed selection of systems for flight development to provide power to a lunar outpost.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| None | Green | Green | Green |



Credit: NASA

Above is an artist's concept of fission surface power technology for lunar exploration.

### Prototype pump shows its capabilities in test

In FY 2010, NASA made progress on a project to develop fission surface power technology options by 2013 to support an expected NASA decision to develop flight power systems.

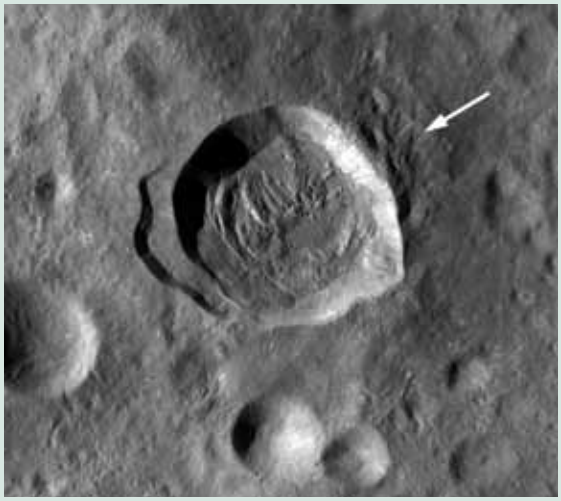
For flexible destinations, crew members would be highly dependent on the power system to achieve mission objectives and assure human safety. Nuclear power systems are best suited for long duration missions that require a robust power capability in difficult environments where solar power is limited.

Specifically, NASA successfully conducted performance testing of a full scale, prototypic electromagnetic Annular Linear Induction Pump (ALIP) with liquid sodium potassium fluid at operating conditions relevant to a future 40 kilowatt surface power system at NASA's Marshall Space Flight Center. ALIP offers highly reliable capability with no moving parts and the potential for very long life—15 to 20 years—without the need for maintenance or repair. In this test, the pump met the flow rate and pressures at operational temperatures of the design specifications. The test results identified design characteristics for ensuring the needed performance levels for space power reactor systems.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| For the Liquid-metal Pump Demonstration, complete final report of performance testing of a prototypic annular linear induction pump with sodium-potassium fluid at operating temperatures and flow rates that are relevant to a future 40 kilowatt fission surface power system. | 7ESRT5 Green | 8AC17 Green | 9AC15 Green | 10AC14 Green |

## *Outcome 6.4: No later than 2020, demonstrate the capability to conduct an extended human expedition to the lunar surface and lay the foundation for extending human presence across the solar system.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | White |



Credit: NASA/Arizona State University

This view of the Necho crater taken by LRO shows impact melt concentrated outside the northeastern rim (indicated by the arrow). Impact melts play a key role in understanding when things happened on the Moon. As rock is melted and then cools and reforms, its internal radiometric clock is reset. By collecting a sample of impact melt scientists can very accurately determine when that crater formed. Since crater rays run out long distances scientists can determine the relative ages of rays, material that underlies rays, and rays that cross other rays. By sampling a few key craters scientists could easily unravel the absolute chronology of some key events on the Moon over the past billion years

**NASA experiments help identify hardware needed for future surface missions**

To embark on a human mission to the Moon or any other planetary body, NASA must gain an understanding of the environment and develop technical capabilities that are more efficient than current technologies. In FY 2010, the Agency evaluated concepts for lightweight composites for large structures that may be useful in Ares V interstage and intertank structures. Researchers evaluated eight architectural concepts and identified both sandwich and stiffened skin concepts for further consideration.

In addition, NASA conducted tests on liquid oxygen and methane engines for possible use on planetary missions where utilization of in-situ resources is a possibility. Scientists at NASA's White Sands Test Facility carried out a total of 48 sea level tests and eight altitude tests on the Aerojet 5,500-pound, liquid oxygen and liquid methane, ascent main workhorse engine. Researchers collected better than expected results based on pretest predictions from the sea level test results.

**NASA collects never before seen images from the Moon**

The Lunar Reconnaissance Orbiter (LRO), an unmanned mission tasked with creating a comprehensive atlas of the Moon's features and resources to aid in the design of a lunar outpost, and the Lunar Crater Observing and Sensing Satellite (LCROSS), which will determine if water ice occurs in an area of permanent shadow near the lunar poles, completed their post launch milestones for FY 2010. The LRO mission provided scientists with invaluable data on the Moon's surface including: images that provide important clues to the moon's recent geologic and tectonic evolution, new details about the entire half of the moon that is obscured from Earth, and imagery of lunar rilles that will help researchers to better understand these mysterious "river-like" features. In accordance with mission success requirements, the project has already submitted more than 50 percent of the gathered data to the Planetary Data System, a database which will help ensure the long-term usability of NASA data and to stimulate advanced research. In a successful completion of its mission, LCROSS discovered water and other volatiles on the lunar surface. Peer-reviewed publications of the LCROSS mission findings will be published in October 2010, in the journal *Science*.

For more information on LRO/LCROSS, please visit *http://lunar.gsfc.nasa.gov/*.

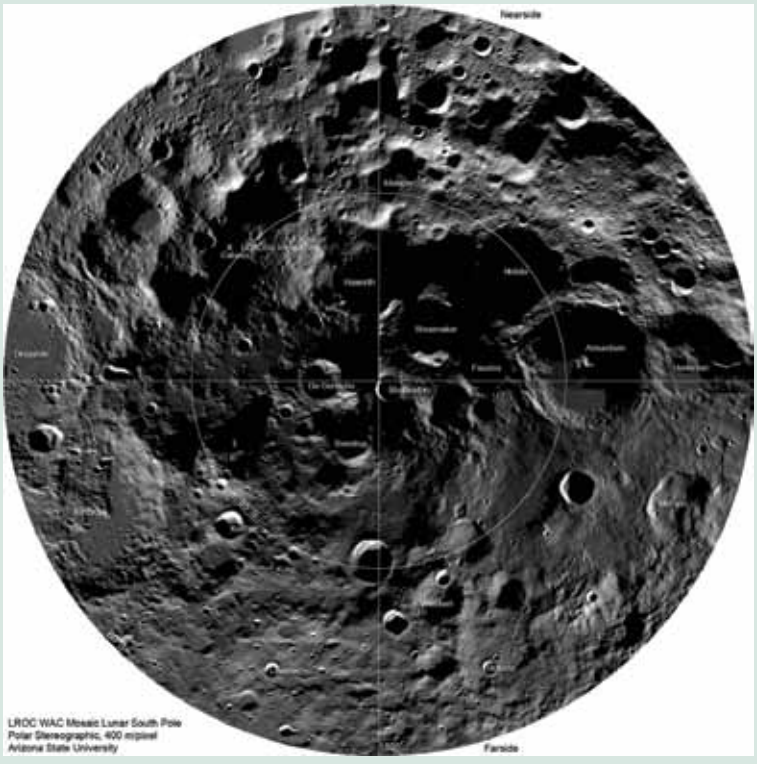
**Why NASA rated Outcome 6.4 White:** In the FY 2011 budget process, the President proposed to Congress that the Constellation Program be transitioned to a new set of programs, and NASA adjusted its spending on the program consistent with its budget request and with the Appropriation provided by Congress for FY 2010. NASA has continued its work on Constellation, but reductions in planned work content were made to ensure availability of funds required to complete work already under contract. These reductions have made it difficult for NASA to achieve some of the Constellation Program-related goals and outcomes planned for FY 2010. While NASA determines how to best transition the Constellation Program, consistent with the NASA Authorization Act of 2010 and its FY 2011 Appropriations Act when final, NASA remains poised to leverage Constellation assets to contribute to future exploration beyond low Earth orbit.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Conduct the Lunar Capabilities Lunar Surface Concept Review (LSCR) to define the lunar mission architecture requirements. | None | 8CS12 Green | 9CS11 Red | 10CS12 White |
| Develop concepts for manufacturing 10-meter diameter composite structures for the Ares V launch vehicle. | None | None | None | 10AC15 Green |
| Test pre-prototype main engine for Altair lunar lander ascent stage using liquid oxygen and liquid methane propellants. | None | None | None | 10AC16 Green |
| Complete LRO's primary mission and deposit 50% of the data to the Planetary Data System. | None | None | 9AC16 Green | 10AC17 Green |
| Complete the Lunar Crater Observation and Sensing Satellite (LCROSS) mission. | None | None | 9AC17 Green | 10AC18 Green |
| Complete at least 3 multilateral workshops with international space agencies to discuss the potential for international participation in exploration activities beyond low Earth orbit. | None | None | None | 10DIO01 Green |
| Facilitate the exchange of at least 10 letters between the NASA Administrator and his international space agency counterparts, introducing the Administrator and outlining his vision for international cooperation. | None | None | None | 10OER01 Green |

**Why NASA rated APG 10CS12 White:** In the FY 2011 budget process, the President proposed to Congress that the Constellation Program be transitioned to a new set of programs, and NASA adjusted its spending on the program consistent with its budget request and with the Appropriation provided by Congress for FY 2010. NASA has continued its work on Constellation, but reductions in planned work content were made to ensure availability of funds required to complete work already under contract. These reductions have made it difficult for NASA to achieve some of the Constellation Program-related goals and outcomes planned for FY 2010. While NASA determines how to best transition the Constellation Program, consistent with the NASA Authorization Act of 2010 and its FY 2011 Appropriations Act when final, NASA remains poised to leverage Constellation assets to contribute to future exploration beyond low Earth orbit.

This mosaic of the lunar South Pole region was created using images taken by LRO. The lunar South Pole is one of the most compelling places in the entire solar system. The towering massifs of the South Pole-Aitken Basin can be accessed, and these massifs contain impact melt that will allow scientists to unambiguously determine the age of this huge basin. Permanently shadowed craters may harbor reservoirs of ices and other volatile compounds that could serve as a tremendously valuable resource for future explorers. Additionally, these volatile deposits could contain a priceless record of water composition dating back to the beginning of the solar system, an incomparable dataset for astrobiology investigations. Finally, a few mountain peaks near the pole (just west and east of the rim Shackleton crater) are illuminated for extended periods of time, which could provide near-constant solar power for a permanent lunar outpost sometime in the far future.

Credit: NASA/Arizona State University



# Cross-Agency Support Programs: Education

| Summary of Ratings for Education | |
|---|---|
| 3 Outcomes | 11 APGs |
| Green = 3 | Green = 9 |
| Yellow = 0 | Yellow = 2 |
| Red = 0 | Red = 0 |
| White = 0 | White = 0 |

| FY 2010 Cost of Performance (Dollars in Millions) |
|---|
| Cross-Agency Support Program costs are distributed among the Strategic Goals. |

NASA performs a leading role in inspiring the next generation of explorers by providing research opportunities, teacher training, lessons, exhibits, and hands-on activities that draw on NASA's unique missions. In 2008, the National Research Council affirmed, NASA has a unique and important role to play in motivating and inspiring students to consider science, technology, engineering, and mathematics (STEM) careers, and citizens to become more knowledgeable participants in the scientific arena. NASA's ambitious missions lead the Nation's exploration of Earth and its climate, the Moon, Mars, and beyond. They also engage teachers and learners of all ages in numerous formal and informal education venues.

NASA's Office of Education aligns the NASA education strategy with national STEM priorities, and actively collaborates with other Federal agencies, and state and local education leaders. The Office of Diversity and Equal Opportunity ensures that education and employment opportunities exist for all, regardless of race, ethnicity, gender, disability, or other status. NASA partners with academic institutions, professional education associations, industry, and other organizations in order to spark student interest and involvement. The Office of Education provides unique experiences to teachers and faculty, allowing them to participate in the excitement of NASA's discoveries. NASA supports students in STEM education, from elementary school through post-secondary degrees. Approaches include providing scholarships and internships, classroom and other instructional resources, on-line learning, education games, contests and competitions, and even controlling NASA's on-orbit research equipment from classrooms.

The Offices of Education and Diversity and Equal Opportunity are committed to recruiting a diverse talent pool, ensuring that NASA resources and opportunities are available to all, and actively engaging women, minorities, and persons with disabilities. The Office of Diversity and Equal Opportunity also takes a proactive role in making sure that NASA's grantees and partners operate in compliance with federal laws preventing discrimination.

## Benefits

NASA's landmark achievements in air and space, made possible by scientific excellence and technical innovation, have deepened humankind's understanding of the universe while yielding down-to-Earth advances in air travel, health care, electronics, computing, and more. These achievements ultimately share a single source—education.

NASA's Office of Education uses NASA's unique missions and vast scientific and technical experience to inspire and motivate America's most important resource—its youth. By providing hands-on opportunities to students of

Photo above: Astronaut Yvonne Cagle poses for a photo with a young guest at Ames Research Center's kick-off event for Summer of Innovation. For more on NASA's Summer of Innovation visit: *http://www.nasa.gov/offices/education/programs/national/summer/home/index.html*. (Credit: NASA/D. Hart)

all ages, engaging them in simulations and authentic research, NASA hopes to stimulate creativity and encourage the growth of a new generation of scientists and engineers. The Agency's Education programs are designed to support NASA by ensuring that a highly skilled, diverse workforce will be available throughout our long-term missions. In the near-term, NASA will meet workforce needs by additional training for current employees and recruiting employees with skills and capabilities in emerging research and technology fields into the Agency.

As part of the longer-term plan, the Office of Education coordinates with the NASA's Offices of Human Capital Management and Diversity and Equal Opportunity to ensure that NASA's portfolio of education investments align with the long-term needs of the Agency. This includes supporting internships and fellowships at NASA Centers, to help inspire students at all levels to pursue STEM-related careers. NASA also provides professional development opportunities to STEM teachers, and develops interesting STEM content for the classroom, the Internet, and informal learning environments like museums and community-based organizations.

# Risks to Achieving Education's Outcomes

The U.S. is facing increasing global competition in the areas of science, technology, innovation, but the performance of American students in math and science disciplines is falling behind other nations. Numerous studies and reports identify future risks to the workforce, economy, and national security if student interest and achievement in these areas are not addressed. NASA's education investments improve STEM teaching ability, increase the scientific literacy of students and the public, enable a better understanding of technology advances, help to build a stronger future STEM workforce, and improve the competitiveness of the Nation.

NASA's education is committed to reaching all learners, regardless of age, race, ethnicity, gender, socioeconomic status, disability, or geographic location. In FY 2009, thirty–nine percent of NASA's higher education students represented races and ethnicities that are underserved/underrepresented in STEM. Forty-two percent of participants were women.

Credit: NASA

## *Outcome ED.1: Contribute to the development of the Science, Technology, Engineering and Math (STEM) workforce in disciplines needed to achieve NASA's Strategic Goals, through a portfolio of investments.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |

Credit: NASA

NASA can help increase the research competitiveness of our Nation's colleges and universities by investing in infrastructures. Programs like the Experimental Program to Stimulate Competitive Research (EPSCoR), build research capability by sponsoring work that enables NASA's missions.

*Note: FY 2009 Higher Education data is used in the FY 2010 PAR because grant reporting cycles for Education align with the calendar year rather than the fiscal year.*

**NASA works to attract diverse student body to STEM**

NASA's higher education STEM programs provide opportunities that attract and prepare increasing numbers of students for careers that benefit NASA and the Nation. Student projects build, sustain, and effectively deploy the skilled, knowledgeable, diverse, and high-performing workforce needed to meet the current and emerging needs of NASA and the Nation's workforce. A second objective is to improve the competitiveness of underrepresented and disadvantaged universities and colleges by supporting research that contributes to the needs of NASA's Mission Directorates, also furthering the Nation's scientific and technology innovation agendas.

NASA makes a strong effort to ensure equal opportunity regardless of race, color, national origin, gender, disability, or age. The Office of Education and Office of Diversity and Equal Opportunity are both contributors to this goal and have realized successes in their programs in the past year. NASA raised the percentage inclusion of racially and ethnically underserved students to 40 percent of all higher education students in FY 2009. The Agency also successfully conducted five onsite Equal Opportunity compliance assessments of STEM programs receiving NASA funding in FY 2010. The Agency conducts such assessments to ensure that federal dollars fund activities that align with the highest standards of equality and fairness. Across the board, NASA has successfully provided targeted technical assistance to programs to help strengthen equality opportunity and inclusion efforts.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Support the development of 60 new or revised courses targeted at the STEM skills needed by NASA. | None | 8ED01 Green | 9ED1 Green | 10ED01 Green |
| Serve 200 institutions in designated EPSCoR states. | None | 8ED02 Green | 9ED2 Green | 10ED02 Green |
| Serve 8,500 under-represented and underserved students in NASA higher education programs. | 7ED2 Green | 8ED03 Green | 9ED3 Red | 10ED03 Yellow |
| Achieve 60% employment of student participants in FY 2009 NASA higher education programs by NASA, aerospace contractors, universities, and other educational institutions. | None | None | 9ED5 Green | 10ED04 Yellow |
| Achieve 45% pursuit of advanced education in NASA-related disciplines of undergraduate students in FY 2009 NASA higher education programs. | None | None | 9ED6 Green | 10ED05 Green |
| Provide equal opportunity (EO) onsite assessment and technical assistance to 3 STEM programs receiving NASA funding, and EO technical assistance to an additional 25 NASA-funded STEM programs. | None | None | None | 10WF11 Green |

**Why NASA did not achieve APG 10ED03:** In FY 2009, 6,743 higher education students self-reported as being part of an underserved and underrepresented race or ethnicity. This represents 40.6 percent of the total number of higher education students served by NASA in FY 2009, an increase from 28 percent of all higher education students similarly reporting in FY 2008. Of all higher education students served by the Agency, 43 percent self-reported being women, an increase from 41 percent in FY 2008. These figures are well above national averages for participation of minority students according to the National Science Foundation's report, *Women, Minorities, and Persons with Disabilities in Science and Engineering*, released in April 2010. The reduction in the number of minority higher education students served (6,743 students rather than the goal of 8,500) also reflects an increased emphasis on institutional awards for education and research, and a corresponding decrease in individual student awards. The overall reduction in direct support to all higher education students in turn affects the total number of higher education underserved and underrepresented students reached by NASA. In FY 2007, the total number of higher education students reached was 34,493; in FY 2008, the number dropped to 24,362, in FY 2009, it dropped further to 24,168. Higher education projects are adjusting to address this trend, but there is significant lag time before results are available (e.g., new course development time, time to execute activities, grant reporting lag time). Another factor adversely influencing the number of individual student awards is the increasing cost of education. To offer individual awards that remain competitive with those of other federal programs and industry, NASA grantees must increase award amounts that meet cost increases in tuition, travel, and other expenses. In a flat or reduced budget environment, an increase in award size means that fewer direct support awards can be made.

**Plans for achieving APG 10ED03:** NASA higher education projects are actively working to increase the participation of underrepresented and underserved students. Future efforts include plans to work more closely with community colleges and institutions that tend to serve large numbers of underserved students. The Space Grant Program, which works with affiliates in all 50 states, the District of Columbia, and Puerto Rico, has actively encouraged state consortia to better engage minority-serving institutions in their networks. The consortia are accountable for improving the participation of underserved students in their programs, determined as a percentage of their audience base. The strategy has been successful, as participation of racially and ethnically underserved and underrepresented students in the Space Grant Program has increased from 15 percent in FY 2007, to 21 percent in FY 2008, and to 29 percent in FY 2009.

**Why NASA did not achieve APG 10ED04:** In FY 2010, NASA's education workforce development target was 60 percent of students from NASA's higher education programs entering into NASA-related careers. Of the 1,343 students who self-reported employment data, 625 students (or 46.5 percent) reported working for NASA, aerospace contractors, universities, or other educational institutions. One project, Motivating Undergraduates in Science and Technology (MUST) was used as a prototype for more closely mapping an Office of Education project directly to the NASA Early Career Hiring Initiative. This collaborate approach succeeded in placing 22 of 29 graduates with NASA

and JPL. The overall drop in employment rate in these specific sectors, relative to previous years, may be a result of uncertainty in NASA's plans (e.g., retirement of Space Shuttle Program, future of the Constellation Program), and overall poor health of the U.S. economy in 2008–2009. However, 38.6 percent of graduates (in addition to those hired by NASA, aerospace industry and educational organizations), chose STEM-related careers. One might conclude that NASA in-depth education experiences are indicative of STEM workforce preparation.

**Plans for achieving APG 10ED04:** NASA organizations with a stake in developing the future workforce will continue to work collaboratively with each other and industry partners to identify future workforce trends and needs. New efforts in the One Stop Shopping Initiative include closer collaboration between NASA's hiring managers and mentors for higher education students.

NASA's Summer of Innovation (SoI) project and the Foundation for the Advancement of Women Now (FFAWN) are working together to encourage young women to pursue exciting experiences and career choices through studying science, technology, engineering and mathematics. A public service announcement featuring veteran NASA Space Shuttle astronaut Leland Melvin and FFAWN's founder, award-winning recording artist Mary J. Blige (shown in this clip taken from the public service announcement), debuted in mid-August 2010 on NASA TV and online.

The common goals SoI and FFAWN share resulted in this unique collaboration. Working with the NASA Science, Engineering, Mathematics and Aerospace Academy project at York College of the City University of New York (CUNY), the joint effort is providing on-the-job training for FFAWN high school participants.

The high school girls participating in the program will be prepared to deliver NASA SoI content to middle school students this summer at the New York City Housing Authority Van Dyke Community Center and the Harlem Children's Zone Promise Academy.

The FFAWN participants will also have the opportunity to support the NASA Academy fall academic session at CUNY as student aides for grades one through nine later this year.

To watch the public service announcement go to *http://www.nasa.gov/multimedia/videogallery/index.html?media_id=17421625*.

## *Outcome ED.2: Attract and retain students in STEM disciplines through a progression of educational opportunities for students, teachers and faculty.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| None | Green | Green | Green |

Credit: NASA

NASA seeks to attract and retain elementary and secondary students in STEM disciplines. Hands on opportunities develop fundamental skills and help increase student awareness of career options.

**NASA uses variety of opportunities to attract students to STEM disciplines**

NASA's ability to inspire student interest and achievement in STEM fields and disciplines of study is based in its unique mission, workforce, facilities, research, and innovations. NASA's Office of Education administers national STEM education programs that draw on content from across the Agency in pursuit of its education goals.

Partnerships and collaborations with national organizations, other space agencies, industry, academia, and other education professionals are an essential element in providing high-quality service to a widespread audience. Partnerships with schools, districts, science centers, and states support the national STEM education imperative and new initiatives. NASA's Elementary and Secondary Education and Informal Education programs inspire and foster achievement in STEM instruction and learning. A few of the approaches include providing research internships at NASA Centers; partnering with colleges of education to deliver workshops and courses for in-service and future educators; flying student developed experiments and hardware on NASA flight platforms (e.g., Space Shuttle, airplanes, sounding rockets, high altitude balloons); partnering with museums, science centers, and community organizations; and helping educators incorporate NASA STEM activities into schools' curriculum or after-school programming. Educational technologies expand the reach of NASA STEM content to audiences that have completed NASA programs or cannot easily access NASA Centers and facilities. Telepresence technologies now allow students and educators to interact with NASA's scientists and engineers, regardless of geographic distance.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Achieve 50% or greater level of interest in science, technology, engineering and math (STEM) careers among elementary and secondary students participating in NASA education programs. | 7ED4 Green | None | 9ED10 Green | 10ED06 Green |
| Increase to 60% the percentage of elementary and secondary educators who either obtain NASA content-based education resources or participate in short-duration NASA education activities, and use NASA resources in their classroom instruction (a 1% annual increase above the FY 2007 baseline of 55%). | 7ED6 Green | 8ED05 Green | 9ED7 Green | 10ED07 Green |
| Increase to 470,000 the number of elementary and secondary student participants in NASA instruction and enrichment activities (a 5% annual increase above the FY 2007 baseline of 408,774). | 7ED6 Green | 8ED04 Green | 9ED8 Green | 10ED08 Green |
| Assure, in FY 2010, 75% of elementary and secondary educators who participate in NASA training programs use NASA resources in their classroom instruction, an annual increase of 5% in the FY 2007 baseline of 62%. | None | None | 9ED9 Green | 10ED09 Green |

## *Outcome ED.3: Build strategic partnerships and linkages between STEM formal and informal education providers that promote STEM literacy and awareness of NASA's mission.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| Green | Green | Green | Green |


Credit: NASA

NASA provides unique opportunities and content access to museums and science centers through its Museum Alliance. Each year, more than 400 institutions of informal education present information on NASA's discoveries and achievements. Activities include speaking engagements, teacher workshops, student camp-ins and family nights, real-time coverage of special events, and exhibits.

### NASA takes STEM education to the public

In FY 2010, NASA promoted a continuous awareness of its Mission and STEM literacy by partnering with the NASA Museum Alliance, the Space Place Network (in every state), the Smithsonian, NASA Visitor Centers, and the Office of Education on a number of special projects. In FY 2010, 400 museums and science centers used NASA resources in programs and exhibits. NASA selected some of these institutions to develop and implement public engagement activities and enhance education programs related to space exploration, aeronautics, space science, Earth science, or microgravity through the Science Museums and Planetarium Grants initiative.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Assure that at least 350 museums and space centers across the country actively engage the public through NASA content. | None | 8ED06 Green | 9ED11 Green | 10ED10 Green |

# Cross-Agency Support Programs: Agency Support

## Contributions from Cross-Agency Support and Programmatic Appropriations Accounts

| Summary of Ratings for Agency Support | |
|---|---|
| 5 Outcomes | 27 APGs |
| Green = 4 | Green = 20 |
| Yellow = 1 | Yellow = 3 |
| Red = 0 | Red = 2 |
| White = 0 | White = 2 |

| FY 2010 Cost of Performance (Dollars in Millions) |
|---|
| Cross-Agency Support Program costs are distributed among the Strategic Goals. |

NASA's Cross-Agency Support Programs (CAS) provide critical mission support activities necessary to ensure the efficient and effective operation and administration of the Agency to include procurement, finance, human capital, information technology, real property and infrastructure, security, diversity, equal opportunity, and small business. Some NASA Offices and Programs that specifically report against Agency performance measures include:

- The Office of Safety and Mission Assurance, which ensures the safety and enhances the success of all NASA activities through the development, implementation, and oversight of Agency-wide safety, reliability, maintainability, and quality assurance policies and procedures;
- The Agency Information Technology Services Program, which provides business and management applications, common information technology (IT) infrastructure, IT security, and IT management services;
- The Strategic Capabilities Assets Program, which ensures that key capabilities and assets, such as wind tunnels and test facilities at Centers, are available for future missions and to help NASA prioritize and make strategic investment decisions to replace, modify, or disposition these capabilities/assets;
- The Human Capital Program which supports and enables NASA's mission by identifying, acquiring, aligning, and sustaining the workforce needed to meet current mission requirements, as well as the challenges that lie ahead; and
- The Office of Equal Opportunity and Diversity which promotes equal employment opportunity (EEO) in NASA's workforce and workplace environment, supports equal opportunity (EO) and diversity-inclusion initiatives and programs to enhance workplace productivity and efficiency, and advances in NASA-funded STEM programs.

The Space Communications and Navigation (SCaN) and the Rocket Propulsion Testing (RPT) programs, both run by the Space Operations Mission Directorate, also contribute to and report against several Cross-Agency Support performance measures. The SCAN program coordinates multiple space communications networks as

Photo above: NASA's Kennedy Space Center and Brevard Workforce host a job fair to help Center employees with future planning and placement as the Space Shuttle Program comes to an end. Kennedy's Human Resources Office, as well as NASA's other Center Human Resources Offices, also host workshops, seminars, and other events to prepare employees as much as possible for future opportunities. (Credit: NASA/K. Shiflett)

well as network support functions to regulate, maintain, and grow NASA's space communications and navigation capabilities in support of all NASA's space missions while the RPT program manages NASA's rocket test propulsion assets, activities, and resources.

## Benefits

These functions align and sustain institutional and program capabilities in support of NASA's mission portfolio requirements by leveraging resources, establishing and maintaining Agency-wide capabilities, and providing institutional checks and balances. CAS institutional capabilities ensure Agency operations are effective, efficient and that activities are conducted in accordance with all statutory, regulatory, and fiduciary requirements. CAS program capabilities ensure vital skills and assets are ready and available to meet technical milestones for programs and projects; ensure research is technically and scientifically sound; and ensure that Agency practices adhere to standards and processes that ensure safety and reliability through proper management of risk.

## Risks to Achieving Cross-Agency Support's Outcomes

NASA continues to rebalance and prioritize mission support capabilities to meet mission requirements. Uncertainties within certain large NASA portfolios increase risk to the Agency across the CAS account. With large new initiatives within CAS for FY 2011, such as the IT consolidation across Agency through the IT Infrastructure Integration Program procurements, the ability for NASA to accommodate new or previously unidentified requirements will be difficult. Funds for high-priority initiatives, such as work force rebalancing, infrastructure deferred maintenance and reduction in Green House Gas Emissions (Federal Sustainability 13514, among other mandates), further constraints the Agency's flexibility to meet emergent and urgent requirements. NASA created the new Mission Support Directorate and Mission Support Council in FY 2010 to assist the Agency in meeting the difficult and dynamic challenges ahead.


## NASA in the Spotlight

### *NASA's Buildings Are Going Green*

NASA is doing its part to help "green" up the Federal government, including some award-winning building initiatives.

The NASA Ames Research Center's Sustainability Base, a candidate for the Leadership in Energy and Environmental Design (LEED) platinum-certified office building, is the winner of this year's U.S. General Services Administration (GSA) Real Property Award in the category of Green Innovation. The award category, Green Innovation, recognizes an innovation or idea with clear potential to transform the Federal community's overall energy and environmental performance.

For more on Ames' Sustainability Base go to *http://www.nasa.gov/externalflash/sustainability-base/index.html*.

In March, the Jet Propulsion Laboratory's (JPL's) environmentally friendly Flight Projects Center received a "Green Building Award" at the fourth annual Green California Leadership Awards. It is NASA's first Gold-certified building under the LEED rating system. The building's green assets include: a "living roof" of desert plants, low-flow faucets and toilets, a "smart" heating and cooling system, showers and bike racks for bike commuters, outdoor lights that reduce light pollution, and many more.

Photo above: A rooftop, drought-resistant garden not only helps insulate the roof of JPL's Flight Projects Center, it also creates an attractive view. (Credit: NASA)

## *Outcome AS.1: Develop, implement, and maintain modern, secure, and high-quality information technology systems and infrastructure to achieve Agency mission objectives with the lowest life-cycle cost and least risk.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| None | None | None | Green |

By advancing NASA's space and research program results through modern, secure, high-quality information technology systems and infrastructure, which are efficient, innovative, reliable, and responsive, at the lowest cost and least risk, the NASA IT organization strives to increase the productivity of scientists, engineers, and mission support personnel.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Complete migration to the NASA Consolidated Active Directory. | None | None | None | 10IT01 Green |
| Complete Operational Readiness Review (ORR) for the NASA Communications Initiative. | None | None | None | 10IT02 Green |
| Complete integration of Personal Identity Verification (PIV) cards with the desktop. | None | None | None | 10IT03 Green |
| Complete planned capacity increase to the NASA Wide Area Network. | None | None | None | 10IT04 Green |
| Complete planned upgrades to networks at Ames Research Center, Glenn Research Center, Goddard Space Flight Center, Kennedy Space Center, Marshall Space Flight Center, and Stennis Space Center. | None | None | None | 10IT05 Green |
| Complete Operational Readiness Review (ORR) for the NASA Security Operations Center. | None | None | None | 10IT06 Red |
| In FY 2010, increase the percentage of total travel bookings completed on-line to at least 60% (baseline is 1.8%). | None | None | None | 10IT08 Green |
| In FY 2010, increase the total number of solicitations developed in PRISM to at least 80%. | None | None | None | 10IT09 Green |
| Reduce runtimes of the most heavily accessed Business Warehouse reports by at least 40%. | None | None | None | 10IT10 Green |

**Why NASA did not achieve APG 10IT06:** The Security Operations Center (SOC) Implementation Project was scheduled to have the ORR this year, but has undergone schedule slips due to delays in facilities power modifications and further delays in receiving IT Security data from numerous sources across the Agency. These delays have negated the ability to complete the testing required in preparation of the Operational Readiness Review.

**Plans for achieving 10IT06:** The SOC Implementation Project will move forward with IT Security event data collection in fall 2010. As the data is obtained, the project will complete final system integration and validation testing. Upon completing validation testing and user training the project will precede to ORR currently scheduled for November FY 2011.

## *Outcome AS.2: Develop and align workforce strategies, programs, policies and processes to be consistent with the Agency's mission.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| None | None | None | Green |

**NASA works to be a model of equal employment opportunity and diversity**

NASA successfully completed all planned actions from the Model EEO Agency Plan for FY 2008–2010 (the Model Plan). The Model Plan is designed to identify, address, and ultimately eliminate deficiencies within the Agency's EEO programs and barriers to employment throughout the Agency. NASA's review in FY 2008 identified deficiencies in its current EEO programs, barriers to the advancement of African American and Asian American males into high-level positions, and inadequate recruitment, hiring, and retention of individuals with disabilities.

In FY 2010, the Agency was able to resolve issues around Section 508 compliance (which requires comparable access for individuals with disabilities to electronic and information technology employed by the Agency) through a comprehensive new policy and greater coordination between key stakeholders (e.g., the Office of the Chief Information Officer, Office of Diversity and Equal Opportunity).

NASA also successfully developed and began implementation of an Agency Diversity and Inclusion Framework. The Framework is designed to assist mission success by fully integrating diversity and inclusion into the strategic decision-making of the Agency and by strengthening efforts to more strategically utilize and expand workforce talents, skills, and opportunities, thus maximizing individual potential and productivity Agency-wide. NASA deployed the first-ever Agency-wide Diversity and Inclusion Assessment Survey, which will help the Agency to develop a Diversity and Inclusion Strategic Implementation Plan to address issues and concerns identified through the survey.

**Nurturing NASA's future leaders**

NASA Mission Directorates, Centers, and other Mission Support Offices collaborated to create a five-year workforce plan that aligns workforce to support the Agency's missions, as proposed to Congress by the President. As part of the plan, the Agency created the Civil Service and Labor Expense account as a solution for funding issues caused by assigning labor costs to programs. The account is intended to assure that sufficient funding is provided for civil service workforce and to provide more flexibility for deploying workforce talents as needed to support NASA's programs. If that account structure is not enacted, NASA will alter the plan as necessary.

The Agency continues to support a 16-month leadership development program for emerging leaders at the GS–13 and –14 level called the Mid-Level Leader Program (MLLP), which began in 2009. Because a high number of current NASA leaders will be eligible for retirement in the next five years, the program assures that emerging leaders are ready to step into their new roles. The program specifically emphasizes tactical application of leadership skills on existing team and organizational challenges. The first cohort was selected in November 2009 and will complete the program in March 2011.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Complete all FY 2010 planned actions for the FY 2008-FY 2010 NASA Model EEO Agency Plan. | None | None | None | 10WF01 Green |
| Complete development of the Agency strategy for deployment of a diversity and inclusion framework. | None | None | None | 10WF02 Green |
| Complete implementation of a certification program to ensure that Program and Project Managers meet Federal Acquisition Certification Requirements before or within one year of assuming leadership of major acquisition projects. | None | None | None | 10WF03 Green |
| Complete full roll-out of the new mid-level leadership development program, targeted at the GS13 through GS15 levels, to ensure continued development of a cadre of potential future NASA leaders and support succession management efforts. | None | None | None | 10WF04 Green |
| Engage with the Mission Directorates, Centers, and Mission Support offices in the development of a 5-year workforce plan, matching workforce capabilities with mission needs. Eliminate unassigned civil service workforce in all years of the planning horizon. | None | None | None | 10WF05 Green |
| By March 2010, complete Phase 4 of Shuttle Transition workforce mapping to identify final detailed Shuttle workforce composition and disposition issues and any required actions. | None | None | None | 10WF06 White |

**Why NASA rated APG 10WF06 White:** NASA completed the first three phases of this effort (approximately 80 to 85 percent of the goal) but has stopped work on Phase Four that is specific to mapping Shuttle workforce to Constellation program activities. The NASA Authorization Act of 2010 and final FY 2011 Appropriations will provide further direction concerning future NASA programs. NASA can then restart the mapping exercise from current to future programs. NASA recognizes the need for mapping its Shuttle workforce to activities consistent with that future direction.

## *Outcome AS.3: Ensure the strategic availability and maintenance of facilities which are necessary to meet the long-term needs and requirements of the Agency.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| None | None | None | Green |

**Ensuring that NASA's assets operate at peak capacity and efficiency**

The Office of Strategic Infrastructure (OSI) assures the timely availability of infrastructure assets and capabilities by reducing the current and future infrastructure related risks to the Agency. OSI accomplishes its mission through effective management of existing infrastructure, enhanced institutional planning and decision-making, proactive deployment of sustainable practices, and disciplined risk management.

In FY 2010, OSI worked with each NASA Center to update their Master Plans for real property and reviewed critical facilities across the Agency to maximize operational capacity and achieve greater efficiencies. For example, during FY 2010, an independent facility review of the V20 and the Sunspot Thermal Vacuum Chamber at Marshall Space Flight Center (MSFC) identified a number of critical safety related concerns that required mitigation. MSFC, using matching funds from the Strategic Capabilities Assets Program within the OSI Technical Capabilities and Real Property Division took immediate action and facilitated the necessary repairs.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Assure that at least 50% of the NASA Centers have updated their Master Plans to implement Agency Strategic Direction from the Facilities Program Board. | None | None | None | 10FAC01 Green |
| Perform a test case review of one of the Agency's major technical portfolios to determine consolidations and/or investments. | None | None | None | 10FAC02 Green |
| Conduct a facility requirements review for the Altair Project requirements through qualification testing. | None | None | None | 10FAC03 White |

**Why NASA rated APG 10FAC03 White:** In the FY 2011 budget process, the President proposed to Congress that the Constellation Program be transitioned to a new set of programs, and NASA adjusted its spending on the program consistent with its budget request and with the Appropriation provided by Congress for FY 2010. NASA has continued its work on Constellation, but reductions in planned work content were made to ensure availability of funds required to complete work already under contract. These reductions have made it difficult for NASA to achieve some of the Constellation Program-related goals and outcomes planned for FY 2010. While NASA determines how to best transition the Constellation Program, consistent with the NASA Authorization Act of 2010 and its FY 2011 Appropriations Act when final, NASA remains poised to leverage Constellation assets to contribute to future exploration beyond low Earth orbit.

## *Outcome AS.4: While promoting mission success, protect the public, NASA workforce, high-value equipment and property from potential harm as a result of NASA activities and operations by factoring safety, quality, risk, reliability, and maintainability as integral features of programs, projects, technologies, operations, and facilities.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| None | None | None | Yellow |

**Safety is their mission**

The Safety and Mission Success (SMS) program administers and refines policies, procedural requirements, and technical standards for NASA. SMS program activities are a key component of the forums that provide advice to the Administrator, Mission Directorates, Program Managers and Center Directors who are ultimately accountable for the safety and mission success of all NASA programs, projects, and operations. The SMS program provides an effective NASA Engineering and Safety Center, NASA Safety Center, and Independent Verification and Validation Facility as established and recognized components of a comprehensive response to lessons learned from NASA's greatest tragedies. These organizations form a basis for a disciplined execution of safety, reliability, quality and system engineering needed for the successful pursuit of NASA's missions. SMS resources provide the foundation for NASA's system of "checks and balances" enabling the effective application of NASA's technical authorities and strategic management framework. With this funding, discipline experts judge the criticality of the associated risk and evaluate the risk acceptability through an established process of independent review and assessment. The information and advice from these experts is critical for developing key decision information for the proper execution of the delegated technical authority applied at program and project decision forums.

**Why NASA did not achieve Outcome AS.4:** There were 12 permanent partial disability (Type B) mishaps that occurred to contract employees during FY 2010.

**Plans for achieving Oucome AS.4:** Policy and procedures are currently in place to provide guidance and education to the NASA workforce (civil service and contractor employees) to minimize mishaps. Management is provided an out brief after each Type A or B mishap with the goal of disseminating information that will reduce the potential for future occurrences.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Assure no fatalities or permanent disabling injuries to the public resulting from NASA activities during the fiscal year. | None | None | None | 10SMS01 Green |
| Assure no fatalities or permanent disabling injuries to the NASA workforce resulting from NASA activities during the fiscal year. | None | None | None | 10SMS02 Red |
| Reduce damage to NASA assets by 10% per fiscal year. | None | None | None | 10SMS03 Green |

**Why NASA did not achieve APG 10SMS02:** There were no fatalities or permanent, total disabilities (Type A) to the NASA workforce during the fiscal year. However, there were 12 permanent partial disability (Type B) mishaps that occurred to contract employees. This was an increase compared to the previous year. There were no Type A or B injuries to NASA civil service employees. NPR 8621.1 defines a Type A mishap as a permanent total disability and Type B as an occupational injury and/or illness that has resulted in a permanent partial disability.

**Plans for achieving 10SMS02:** Policy and procedures are currently in place to provide guidance and education to the NASA workforce (civil service and contractor employees) to minimize mishaps. Management is provided an out brief after each Type A or B mishap with the goal of disseminating information that will reduce the potential for future occurrences.

# *Outcome AS.5: Implement the space communications and navigation architecture and provide space launch capabilities responsive to existing and future science and space exploration mission requirements.*

| FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|
| None | None | None | Green |

**NASA's communication networks continue to deliver**

An uninterrupted, reliable communications and navigation network is essential to receive and transmit the data that makes NASA missions safe, efficient, and successful. Currently, NASA's communications network consists of three main elements: the Space Network, the Near-Earth Network, and the Deep Space Network. NASA's Goddard Spaceflight Center leads and operates the Space and Near-Earth Networks and the Jet Propulsion Laboratory operates the Deep Space Network. These networks provide communications and tracking to all orbiting NASA assets, everything from the International Space Station to spacecraft orbiting Earth and traveling out to the very edge of the solar system.

However, operating these networks has become increasingly more expensive, which has motivated NASA to investigate potentially more cost-effective solutions. In FY 2010, NASA's Space Communications and Navigation (SCaN) program continued its development of a unified space communication and navigation network capable of meeting both robotic and human exploration needs. To this end, NASA awarded a contract which will provide major modernization upgrades to the Space Network Ground Segment (SGSS) as well as the architectural basis for further integration of the SCaN networks towards a single, integrated network. Likewise, NASA addressed Deep Space Network facility issues by releasing a Request for Proposal for 70 meter Antenna Replacement project with award anticipated in early FY 2011.

In FY 2010, ScaN's Communication, Navigation and Networking, reConfigurable Testbed (CoNNeCT) and its Lunar Laser Communication Demonstration (LLCD) technology projects successfully completed Critical Design Reviews, which are one-time programmatic events that bridge the design and manufacturing stages of a project. A successful review means that the design is validated, will meet its requirements, and has been proven to be safe. The LLCD is an experiment to provide the proof-of-concept for laser-based communications from lunar orbit, which could result in overall cost savings on the ground and in space, while providing more capability. It is a significant step for the Agency in becoming more efficient with its limited resources.

The Space Network supported missions this year at or above 99.9 percent proficiency, exceeding requirements. Key missions supported include the Space Shuttle, International Space Station, Hubble Space Telescope, and the Terra Earth science mission. The Deep Space Network-supported missions this year at or above 95 percent proficiency for both telemetry and command, also exceeding requirements. Key missions supported include Cassini, Kepler, Mars Reconnaissance Orbiter, and Mars Exploration Rovers. The Near Earth Network supported missions this year at or above 99.1 percent proficiency, above requirements. Key missions supported include the LRO, Hinode, Aqua, and Aura missions.

**NASA Preparing for the Next Generation of Rockets**

NASA's RPT activities continued to support the Agency's core capabilities and needs. Efforts continue through the National Rocket Propulsion Test Alliance (NRPTA) to identify NASA, Department of Defense, and commercial capabilities and requirements over the next 10 years. The results will be identified in the NASA RPT Master Plan due to be released at the end of calendar year 2010. Over the next year, RPT will begin the implementation of recommendations from the 2009–2010 White Sands Test Facility capabilities study as part of its responsibilities to maintain Agency RPT core capabilities (both infrastructure and critical skills) at appropriate levels to be able to meet NASA's current and future rocket testing requirements.

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| Complete the assessment of Array Antenna size in support of the long-term plans for the 70 meter antenna decommissioning and replacement. | None | None | None | 10SFS06 Green |
| Complete TDRS K/L Project Mission Operations Review (MOR). | None | None | 9SFS6 Green | 10SFS07 Yellow |
| Complete SN Ground Segment Sustainment project (SGSS) Mission Definition Review. | None | None | None | 10SFS08 Yellow |
| Identify agency rocket propulsion test core capabilities (both infrastructure and critical skills) and maintain them at appropriate levels to be able to meet NASA's current and future rocket testing requirements, and deliver an integrated Agency-level Rocket Propulsion Test Plan that spans the next 10 years and includes DoD and commercial partner requirements and capabilities, as appropriate. | None | None | 9SFS4 Yellow | 10SFS09 Yellow |
| Maintain or acquire launch services capabilities (both infrastructure and skills) at levels needed to meet NASA's current and future launch services requirements efficiently and effectively. | None | None | None | 10SFS10 Green |
| Complete 100% of Launch Service objectives for all NASA-managed expendable launches in FY 2010 as specified in the Interface Control Document for each mission. | None | None | None | 10SFS11 Green |

**Why NASA did not achieve APG 10SFS07:** The TDRS project had originally scheduled the K/L MOR for September 2010 but was delayed to resolve minor conflicts involving resources.

**Plans for achieving 10SFS07:** The MOR will be held in November 2010.

**Why NASA did not achieve APG 10SFS08:** The SGSS Mission Definition Review did not occur as planned due to an ongoing contractor protest.

**Plans for achieving 10SFS08:** NASA will develop a new plan and schedule for completing the Mission Definition Review once the protest is adjudicated.

**Why NASA did not achieve 10SFS09:** The Agency-level Rocket Propulsion Test Plan due date was re-negotiated and agreed upon between NASA and the Office of Management and Budget; new due date is December 31, 2010.

**Plans for achieving 10SFS09:** The Rocket Propulsion Test Plan is on schedule to meet the December 31, 2010, deadline.

# NASA's Uniform and Efficiency Measures

NASA uses Uniform and Efficiency Measure APGs to track performance in a number of program and project management areas, including life cycle schedule and cost and competitive award processes. NASA organizes the Efficiency Measure APGs by Theme to emphasize and encourage individual program accountability.

| 34 APGs | | | |
|---|---|---|---|
| Green | Yellow | Red | White |
| 22 | 1 | 7 | 4 |

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| **Advanced Capabilities Theme** | | | | |
| **Complete all development projects within 110% of the cost and schedule baseline.** | None | None | 9AC18 Yellow | 10AC19 White |
| *Why NASA rated APG 10AC19 White:* There were no projects in development in the Advanced Capabilities Theme in FY 2010, and none are planned for FY 2011. | | | | |
| **Demonstrate improvements in the EVA Work Efficiency Index for astronauts using a small, pressurized rover with suit-ports compared to astronauts using an unpressurized rover. Work efficiency index = (time to complete a task)/(total time to prepare for EVA).** | None | None | 9AC20 Green | 10AC20 Green |
| **Aeronautics Theme** | | | | |
| **Deliver at least 96% of "on-time availability" for all operations and research facilities.** | 7AT8 Yellow | 8AT17 Yellow | 9AT12 Green | 10AT13 Green |
| **Agency Support** | | | | |
| **Reduce energy intensity for facility energy use by 3% per year, from the FY 2003 baseline, for a total reduction of 30% (in Btu/gsf) by the end of FY 2015.** | None | None | None | 10FAC04 Red |
| *Why NASA did not achieve APG 10FAC04:* Energy intensity is decreasing an average of 1 percent annually, and energy unit costs are increasing an average of 7.2 percent annually.<br><br>*Plans for achieving APG 10FAC04:* NASA is working to meet energy intensity reduction requirements of 3 percent per year and 30 percent by 2015, from the FY 2003 baseline. In an effort to assist Centers to administer their energy management programs, NASA Headquarters conducts Energy and Water Management Functional Reviews at a third of NASA Centers annually to help Centers in improving their management systems and identifying and implementing energy conservation measures. In FY 2010, NASA invested $66 million for construction and revitalization projects at four NASA Centers that include major replacements of aging high energy use equipment with new energy efficient units, and initiated an Inter-Center Competition to reduce energy/water consumption. The competition encourages Centers to implement low-cost and no-cost initiatives to reduce energy and water usage. NASA will allocate $4 million of Strategic Institutional Investment funds for small energy and renewable projects in FY 2011 and an additional $22.3 million in FY 2012. This past fiscal year, NASA also initiated a Recapitalization Program that will replace aging facilities with new more energy efficient buildings. | | | | |
| **Reduce total fleet consumption of petroleum products by 2% per year, from the FY 2005 baseline, for a total of reduction of 30% by the end of FY 2020.** | None | None | None | 10FAC05 Green |
| **Reduce potable water use by 2% per year, from the FY 2007 baseline, for a total reduction of 26% (in gal/gsf) by the end of FY 2020.** | None | None | None | 10FAC06 Green |
| **Achieve a number of technology commercialization successes from SBIR/STTR Phase II contracts through FY 2010 to equal 21% of the total number of SBIR/STTR contracts issued over the prior 5 years, including FY 2010.** | None | None | None | 10IPP08 Green |

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| **Complete all development projects within 110% of the cost and schedule baseline.** | None | None | None | 10IT11 Red |
| ***Why NASA did not achieve APG 10IT11:*** All but one project finished within the required 110 percent of cost and schedule baselines. The Security Operations Center (SOC) implementation (Phase-2) project has undergone schedule slips, due to delays in facilities power modifications resulting in delays of receiving IT Security event data from numerous sources across the Agency. The delay in having adequate power to the facility kept the SOC from being able to capture data, thereby not allowing testing and not being ready to complete the ORR. The extra power lines and resultant coordination were not planned for when the project was initially scoped and were beyond the initial project plan estimates. The final SOC implementation plan will increase cost to 145 percent and schedule to 161 percent of the initial project scope. NASA reviewed this project during implementation, and given the importance of IT security, approved additional time and funding for the project. | | | | |
| ***Plans for achieving APG 10IT11:*** There are no options to achieving this goal. NASA determined the IT Security Operations Center project implementation fits into the CyberSecurity scope and needed to be accomplished to protect NASA's IT vulnerability. | | | | |
| **In 2010, reduce the amount of system execution time during the year-end close process by six hours.** | None | 8IEM07 Red | 9IEM9 Red | 10IT12 Green |
| **Deliver at least 90% of scheduled operating hours for all operations.** | None | None | None | 10IT13 Green |
| **Using the Agency's Staffing and Recruitment System, NASA STARS, complete hiring actions—from date of vacancy announcement closing to the time an offer is made—within 45 days.** | None | None | None | 10WF07 Green |
| **Astrophysics Theme** | | | | |
| **Complete all development projects within 110% of the cost and schedule baseline.** | 7UNIV9 Red | 8AS09 Yellow | 9AS12 Yellow | 10AS11 Green |
| **Deliver at least 90% of scheduled operating hours for all operations and research facilities.** | 7UNIV10 Green | 8AS10 Green | 9AS13 Green | 10AS12 Green |
| **Peer-review and competitively award at least 95%, by budget, of research projects.** | 7UNIV11 Green | 8AS11 Green | 9AS14 Green | 10AS13 Green |
| **Reduce time within which 80% of NRA research grants are awarded, from proposal due date to selection, by 5% per year, with a goal of 130 days.** | 7UNIV12 Green | 8AS12 Yellow | 9AS15 Green | 10AS14 Green |
| **Constellation Systems Theme** | | | | |
| **Complete all development projects within 110% of the cost and schedule baseline.** | 7CS9 White | 8CS14 White | 9CS14 White | 10CS13 White |
| ***Why NASA rated APG 10CS13 White:*** In the FY 2011 budget process, the President proposed to Congress that the Constellation Program be transitioned to a new set of programs, and NASA adjusted its spending on the program consistent with its budget request and with the Appropriation provided by Congress for FY 2010. NASA has continued its work on Constellation, but reductions in planned work content were made to ensure availability of funds required to complete work already under contract. These reductions have made it difficult for NASA to achieve some of the Constellation Program-related goals and outcomes planned for FY 2010. While NASA determines how to best transition the Constellation Program, consistent with the NASA Authorization Act of 2010 and its FY 2011 Appropriations Act when final, NASA remains poised to leverage Constellation assets to contribute to future exploration beyond low Earth orbit. | | | | |
| **Total annual cost of Constellation operations activities for the first full year after full operational capability, will be no greater than 70% of comparable annual Shuttle operations costs (reference year FY 2007).** | None | 8CS15 Green | 9CS13 White | 10CS14 White |
| ***Why NASA rated APG 10CS14 White:*** In the FY 2011 budget process, the President proposed to Congress that the Constellation Program be transitioned to a new set of programs, and NASA adjusted its spending on the program consistent with its budget request and with the Appropriation provided by Congress for FY 2010. NASA has continued its work on Constellation, but reductions in planned work content were made to ensure availability of funds required to complete work already under contract. These reductions have made it difficult for NASA to achieve some of the Constellation Program-related goals and outcomes planned for FY 2010. While NASA determines how to best transition the Constellation Program, consistent with the NASA Authorization Act of 2010 and its FY 2011 Appropriations Act when final, NASA remains poised to leverage Constellation assets to contribute to future exploration beyond low Earth orbit. | | | | |

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| **Earth Science Theme** | | | | |
| **Complete all development projects within 110% of the cost and schedule baseline.** | 7ESS21 Yellow | 8ES15 Yellow | 9ES21 Red | 10ES17 Red |
| ***Why NASA did not achieve APG 10ES17:*** NASA did not complete the Glory and Aquarius missions within 10 percent of their cost and schedule baselines.<br><br>***Plans for achieving APG 10ES17:*** The Glory mission experienced significant cost and schedule growth due primarily to the failure of the Orbiting Carbon Observatory (OCO) Taurus XL launch vehicle and issues with the vendor's production of acceptable boards for the Maxwell Single Board Computers. Glory's current projected lifecycle cost is 68 percent higher than the baseline established at Confirmation Review. The mission is tentatively scheduled for a February 2011 launch readiness date, a 72 percent increase in schedule. The Aquarius launch readiness date has been rescheduled for April 2011 due to delays in the development of the international partner's Mission Operations System. The schedule for the mission has increased by 60 percent, but the lifecycle cost remains within 15 percent of the baseline. | | | | |
| **Deliver at least 90% of scheduled operating hours for all operations and research facilities.** | 7ESS22 Green | 8ES16 Yellow | 9ES22 Green | 10ES18 Green |
| **Peer-review and competitively award at least 90%, by budget, of research projects.** | 7ESS23 Green | 8ES17 Green | 9ES23 Green | 10ES19 Green |
| **Reduce time within which 80% of NRA research grants are awarded, from proposal due date to selection, by 5% per year, with a goal of 227 days.** | 7ESS24 Red | 8ES18 Green | 9ES24 Red | 10ES20 Yellow |
| ***Why NASA did not achieve APG 10ES20:*** The time within which 80 percent of the Earth Science selection notifications were made decreased in FY 2010 to 231 days, but fell just short of the ultimate goal of 227 days, which it was scheduled to achieve this fiscal year.<br><br>***Plans for achieving APG 10ES20:*** The Science Mission Directorate continues to implement changes to reduce delayed selection notifications. These include the scheduling of proposal due dates to spread out the work for the understaffed research program managers and providing tentative notification to proposers when budget uncertainty (e.g., lack of appropriations, lack of operating plan) delays final decision authority. | | | | |
| **Education Theme** | | | | |
| **Reduce the dollar invested per number of page views for the NASA Education Web site.** | None | None | 9ED13 Green | 10ED11 Green |
| **Reduce the cost per elementary and secondary school program participant over FY 2009 amounts by 2%.** | None | None | 9ED14 Red | 10ED12 Red |
| ***Why NASA did not achieve APG 10ED12:*** Research in science, technology, engineering, and mathematics (STEM) education shows that projects and activities that provide hands-on experiences, intensive internships, and sustained educator professional development relationships are more effective in positively affecting STEM teaching and learning. NASA's Office of Education has strategically adjusted its elementary and secondary portfolio to include greater investments in these types of experiences. They are more costly, but more effective in improving teaching and learning than short-term, broad-based activities like one-time workshops, auditorium-style presentations and school visits. Elementary and secondary education programming is changing direction within a flat-line (or decreasing core program budget), and this goal is no longer feasible.<br><br>***Plans for achieving APG 10ED12:*** This performance goal has been determined to be unattainable as written and will be replace by a more appropriate measure in FY 2011. | | | | |
| **Heliophysics Theme** | | | | |
| **Complete all development projects within 110% of the cost and schedule baseline.** | 7ESS21 Yellow | 8HE07 Red | 9HE10 Yellow | 10HE09 Red |
| ***Why NASA did not achieve APG 10HE09:*** NASA did not complete the Solar Dynamics Observatory (SDO) within 110 percent of cost and schedule baselines. SDO initially slipped from its 2008 firm slot in the launch manifest due to late delivery of avionics boxes and instruments and problems with electronics parts and the high-speed data bus. SDO then experienced difficulty obtaining a new slot in the launch manifest, as no firm slots were available until 2010 due to multiple Atlas V launch vehicle issues and associated launch queue delays.<br><br>***Plans for achieving APG 10HE09:*** NASA launched SDO in February 2010. This exceeded the original schedule by 48 percent, but the mission's lifecycle cost remains within 7 percent of the original cost baseline. | | | | |

| FY 2010 Annual Performance Goals | FY07 | FY08 | FY09 | FY 2010 |
|---|---|---|---|---|
| **Reduce time within which 80% of NRA research grants are awarded, from proposal due date to selection, by 5% per year, with a goal of 130 days.** | 7ESS24 Red | 8HE10 Yellow | 9HE13 Green | 10HE12 Red |
| *Why NASA did not achieve APG 10HE12:* The time within which 80 percent of Heliophysics selection notifications were made increased in FY 2010 to 235 days, exceeding the goal of 215 days. | | | | |
| *Plans for achieving 10HE12:* The Science Mission Directorate continues to implement changes to reduce delayed selection notifications. These include the scheduling of proposal due dates to spread out the work for the understaffed research program managers and providing tentative notification to proposers when budget uncertainty (e.g., lack of appropriations, lack of operating plan) delays final decision authority. | | | | |
| **International Space Station Theme** | | | | |
| **Deliver at least 90% of scheduled operating hours for all operations and research facilities.** | 7ISS7 Green | 8ISS07 Green | 9ISS8 Green | 10ISS09 Green |
| **Planetary Science Theme** | | | | |
| **Peer-review and competitively award at least 95%, by budget, of research projects.** | 7SSE12 Green | 8PS11 Green | 9PS13 Green | 10PS13 Green |
| **Reduce time within which 80% of NRA research grants are awarded, from proposal due date to selection, by 5% per year, with a goal of 130 days.** | 7ESS13 Red | 8PS12 Green | 9PS14 Green | 10PS14 Red |
| *Why NASA did not achieve APG 10PS14:* The time within which 80 percent of Planetary Science selection notifications were made increased in FY 2010 to 243 days, exceeding the goal of 221 days. | | | | |
| *Plans for achieving APG 10PS14:* The Science Mission Directorate continues to implement changes to reduce delayed selection notifications. These include the scheduling of proposal due dates to spread out the work for the understaffed research program managers and providing tentative notification to proposers when budget uncertainty (e.g., lack of appropriations, lack of operating plan) delays final decision authority. | | | | |
| **Complete all development projects within 110% of the cost and schedule baseline.** | 7SSE10 Red | 8PS09 White | 9PS11 Red | 10PS15 White |
| *Why NASA rated APG 10PS15 White:* This is a standing uniform efficiency measure that is not applicable in this fiscal year. No Planetary Science missions were scheduled to launch in FY 2010. | | | | |
| **Deliver at least 90% of scheduled operating hours for all operations and research facilities.** | 7SSE11 Green | 8PS10 Green | 9PS12 Green | 10PS16 Green |
| **Space and Flight Support Theme** | | | | |
| **Achieve at least 99% Space Network proficiency for delivery of Space Communications services.** | None | 8SFS04 Green | 9SFS10 Green | 10SFS12 Green |
| **Complete all development projects within 110% of the cost and schedule baseline.** | 7SFS5 White | 8SFS06 White | 9SFS11 Green | 10SFS13 Green |
| **Ratio of Launch Services Program cost per mission to average spacecraft cost, reduced to 6.2%.** | None | None | 9SFS12 Green | 10SFS14 Green |
| **Space Shuttle Theme** | | | | |
| **Deliver at least 90% of scheduled operating hours for all operations and research facilities.** | 7SSP5 Green | 8SSP06 Green | 9SSP6 Green | 10SSP06 Green |

# NASA's Performance Improvement Plan Update for FY 2009

NASA holds itself accountable for achieving the Performance Improvement Plans set in the previous fiscal year. In FY 2009, NASA rated a total of 38 measures as red or yellow and provided individual Performance Improvement Plans for remedying each performance shortfall. The table below lists each unmet FY 2009 measure, with its performance improvement plan and provides the most recent information on the Agency's efforts to achieve the measures. As a best practice, NASA also will provide a Performance Improvement Plan Update in the FY 2011 PAR to assure the public of the Agency's continued commitment to excellence in performance and accountability.

| Description | Rating | Why the Measure Was Not Met | Plans for Achieving the Measure in FY 2009 |
|---|---|---|---|
| **Aeronautics Research Mission Directorate** | | | |
| **Aeronautics** | | | |
| 9AT2 (Outcome 3E.1) | | | |
| Conduct a spin test to verify enhanced disk rim attachment strength at component level and show 10% life improvement over criteria established in 2007. | Yellow | The final spin test to validate the performance did not occur prior to the end of FY 2009 because of test facility problems. NASA Glenn Research Center delivered two superalloy disks and an oven to the Space Act Agreement (SAA) partner, who agreed to conduct a Spin Pit Test on the superalloy to see if the disk could withstand 10,000 cycles at 1,300 degrees Fahrenheit. In April 2009, the SAA partner began calibrating the government-provided oven to ensure it maintained an acceptable 1,300 degrees Fahrenheit. During this checkout, the oven did not maintain a stable temperature. As a result, the SAA partner purchased a new oven that was delivered and checked out by July 31, 2009, resulting in a normal two-week shutdown of the test facilities. During calibration on August 10, 2009, the new oven met temperature requirements, but failed due to mechanical reasons. Replacement parts have been ordered, and the checkout of the oven is scheduled for September 8, 2009. The testing period for the superalloy disks is expected to last a couple of weeks, following successful calibration of the oven. While ARMD still expects performance consistent with a green rating and completion of milestone before September 30, 2009. However, since the analysis to support the APG will not be complete until after October 1, 2009, ARMD supports a rating of Yellow. | The test will proceed as planned and analysis will be conducted and completed in the first quarter of FY 2010 |
| **FY 2010 Update:** NASA completed the spin test during the third quarter of FY 2010. The disk reached the 10,000 dwell cycle goal and achieved a green exit criteria. The redesigned arbor and fixtures performed to specifications enabling the test to be performed at 1300 °F. A post test inspection revealed no radial growth of the disk and no change in the attachment hole dimensions. Following the spin test, the disk was sent to an FAA authorized Non-Destructive Inspection vendor for a Class 3 Fluorescent Penetrant Inspection. No cracks were detected. Final room temperature disk burst test was performed. The predicted burst speed was 80,000 revolutions per minute (rpm) and the disk burst at 80,480 rpm, within 1.0 percent of predicted speed. FEM analysis also correctly predicted location of crack initiation. | | | |

| Description | Rating | Why the Measure Was Not Met | Plans for Achieving the Measure in FY 2009 |
|---|---|---|---|
| 9AT10 (Outcome 3E.3) | | | |
| Complete the CFD pretest predictions of performance and operability of a high Mach fan for a TBCC propulsion system and compare to fan test data from the GRC W8 facility. | Yellow | NASA completed an extensive test program for the fan of a Mach 4 turbine engine. Researchers used the data from this effort to validate NASA's advanced Computational Fluid Dynamics (CFD) codes for turbine analysis and to validate the NASA and General Electric design methodology. All of the stall margin points, with the exception of one, were well within the APG's Green criteria of a five-percent difference. However, the predictions were outside the pre-established metric. The NASA effort to develop Mach 4 turbine engines is a very significant and challenging advancement to the state-of-the-art. The efficiency goal set by the NASA team of 0.25 percent, is very aggressive, especially considering that this was the first attempt at such predictions for a Mach 4 design. Typical efficiency errors for less complex fans are usually in the range of 0.4 percent to one percent, which is consistent with the results from this high-speed test. | The primary reason that the goal was not met is that NASA set very aggressive metrics, especially for the efficiency predictions. This was done to push the limits of NASA's ability to predict challenging conditions, and should not be interpreted as a failure of the prediction methods. NASA will continue to investigate how prediction capabilities can be improved, based on an analysis of the results and comparison with other state-of-the-art prediction methods on less sophisticated fans. This initial set of experiments and predictions were successful and work is proceeding on more complex testing that permits additional advances. The overall turbine-based combined cycle (TBCC) effort continues with the installation and testing of the TBCC inlet system in the Glenn Research Center 10-by-10-foot Supersonic Wind Tunnel in FY 2010. |
| **FY 2010 Update:** The ability to predict the compressor efficiency within 0.4 percent remains the state-of-the art for advanced high-fidelity turbomachinery Computational Fluid Dynamics (CFD) codes. This level of CFD code accuracy was deemed sufficient so that the more relevant distorted inlet flow research on the Mach 4 fan could proceed. The distorted inlet flow case directly supports NASA research for the turbine-based combined cycle (TBCC) effort mentioned previously. Note that the FY 2009 APG 9AT10 addressed the uniform inlet flow case only for the Mach 4 fan. In the future, NASA plans to continue to improve and validate state-of-the-art CFD codes for turbine design and analysis, but this work has not yet been planned for the near-term. | | | |
| **Exploration Systems Mission Directorate** | | | |
| **Constellation** | | | |
| Outcome 4.1 | | | |
| No later than 2015, and as early as 2010, transport three crewmembers to the International Space Station and return them safely to Earth, demonstrating an operational capability to support human exploration missions. | Yellow | As with any major development program in formulation, the Constellation Program continues to perform detailed budget and schedule analysis to ensure that each project's budget and content are optimized to successfully meet the March 2015 Initial Operation Capability (IOC). During the FY 2010 Budget Request cycle, NASA did a replan, which resulted in the realignment of some major milestones. This resulted in a delay in some major milestones reflected in the yellow rating of several FY09 APGs, but preserved the March 2015 IOC date. NASA is currently in the process of reviewing its latest cost and schedule confidence in advance of the Key Decision Point (KDP)-II, which will move the program into the Implementation phase. | In summer 2010, NASA will hold Ares I, Orion, and Ground Operations Key Decision Point C reviews to decide if each are ready to enter development. At this time, Constellation also will go through its second KDP review, allowing the program to enter implementation. The Mission Operations and Extravehicular Activity (EVA) projects will have their PDRs, preparing them for their KDP-C reviews. Additionally, Constellation made significant progress in understanding and integrating project interdependencies, allowing for improved integration of scheduling and helping the program get back on track to achieve the Outcome. |
| **FY 2010 Update:** In FY 2010, the Constellation Program completed the Technical Preliminary Design Review (PDR) for Constellation in March 2010, the Ground Operations Project PDR in June 2010, and completed Ares I-X launch test, the Orion Pad Abort-1 test, and the Ares I Development-Motor 2 (DM-2) test. | | | |

| Description | Rating | Why the Measure Was Not Met | Plans for Achieving the Measure in FY 2009 |
|---|---|---|---|
| 9CS1 (Outcome 4.1) | | | |
| Complete the Critical Design Review (CDR) for the Orion / Crew Exploration Vehicle (CEV). | Red | Constellation established the milestone date used for this APG when the project was still in early formulation. Since then the project's schedule has been refined and the milestone pushed to a later date to align with the Constellation Program's replanned schedule. | The Orion project has been following the schedule set by the Constellation Program. The project continued to perform Design Analysis Cycles through summer 2009, which led to a successful PDR in July and August. The next major milestone on Orion's schedule is the KDP-C review set for summer 2010. The Orion Critical Design Review (CDR) follows that review in FY 2011. |
| **FY 2010 Update:** In the FY 2011 budget process, the President proposed to Congress that the Constellation Program be transitioned to a new set of programs, and NASA adjusted its spending on the program consistent with its budget request and with the Appropriation provided by Congress for FY 2010. NASA has continued its work on Constellation, but reductions in planned work content were made to ensure availability of funds required to complete work already under contract. These reductions have made it difficult for NASA to achieve some of the Constellation Program-related goals and outcomes planned for FY 2010. While NASA determines how to best transition the Constellation Program, consistent with the NASA Authorization Act of 2010 and its FY 2011 Appropriations Act when final, NASA remains poised to leverage Constellation assets to contribute to future exploration beyond low Earth orbit. | | | |
| 9CS3 (Outcome 4.1) | | | |
| Complete the Critical Design Review (CDR) for the Pad B Launch Complex development within the Ground Operations Project. | Yellow | The Constellation Program changed the Ground Operations Pad B Launch Complex milestone dates in accordance with the program's revised schedule. | NASA plans to hold the CDR for the Pad B Launch Complex in summer 2010. |
| **FY 2010 Update:** In the FY 2011 budget process, the President proposed to Congress that the Constellation Program be transitioned to a new set of programs, and NASA adjusted its spending on the program consistent with its budget request and with the Appropriation provided by Congress for FY 2010. NASA has continued its work on Constellation, but reductions in planned work content were made to ensure availability of funds required to complete work already under contract. These reductions have made it difficult for NASA to achieve some of the Constellation Program-related goals and outcomes planned for FY 2010. While NASA determines how to best transition the Constellation Program, consistent with the NASA Authorization Act of 2010 and its FY 2011 Appropriations Act when final, NASA remains poised to leverage Constellation assets to contribute to future exploration beyond low Earth orbit. | | | |
| 9CS4 (Outcome 4.1) | | | |
| Complete the Preliminary Design Review (PDR) of the Mission Control Center System (MCCS) within the Mission Operations Project. | Yellow | The Constellation Program changed the Mission Operations project's schedule, and the project did not mature the Mission Control Center System to the point where it could undergo the PDR. | NASA has made it possible for mature subsystems for the Mission Control Center System to proceed with a PDR and then allow those subsystems to begin working toward their CDR. The Mission Operations project will have the entire Mission Control Center System ready for its PDR in summer 2010. |
| **FY 2010 Update:** NASA completed PDR of the Mission Control Center System on February 11, 2010. The results of this PDR were incorporated into the Mission Operations Project (MOP) PDR, which was completed August, 17, 2010. | | | |
| 9CS5 (Outcome 4.1) | | | |
| Complete the Preliminary Design Review (PDR) for the Extravehicular Activity (EVA) Space Suit Element for CEV. | Red | The Constellation Program changed the project's schedule when the program did its replan. | As part of the Orion PDR, the Constellation Program identified what was required tomake the EVA spacesuit design work with the Orion spacecraft systems, and the two projects have integrated their hardware development, associated analyses, and related milestones. The EVA Suit Configuration 1 PDR is scheduled for September 2010, which enables the Constellation Space Suit System prime contractor an opportunity to mature the rest of the system. |
| **FY 2010 Update:** In the FY 2011 budget process, the President proposed to Congress that the Constellation Program be transitioned to a new set of programs, and NASA adjusted its spending on the program consistent with its budget request and with the Appropriation provided by Congress for FY 2010. NASA has continued its work on Constellation, but reductions in planned work content were made to ensure availability of funds required to complete work already under contract. These reductions have made it difficult for NASA to achieve some of the Constellation Program-related goals and outcomes planned for FY 2010. While NASA determines how to best transition the Constellation Program, consistent with the NASA Authorization Act of 2010 and its FY 2011 Appropriations Act when final, NASA remains poised to leverage Constellation assets to contribute to future exploration beyond low Earth orbit. | | | |

| Description | Rating | Why the Measure Was Not Met | Plans for Achieving the Measure in FY 2009 |
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| 9CS6 (Outcome 4.1) | | | |
| Complete the launch and flight analysis of the CEV Pad Abort 1 (PA-1) test. | Yellow | Unanticipated difficulties during subscale testing (where the project team test a smaller-scale engineering model) of the Attitude Control Motor (ACM) delayed the Pad Abort-1 (PA-1) flight test. | Due to the difficulties during testing, the project changed the design. Two successful subscale test firings with the new design indicated that the project has overcome the challenges. A full-scale test firing of the ACM is scheduled for fall 2009, and the Orion project remains on track to conduct the PA-1 test in early 2010. These tests are for a Launch Abort System that will allow the crew to jettison clear of the Ares I rocket in case of emergency before launch. This is a safety feature that has not been available on NASA's previous space transportation systems. |
| **FY 2010 Update:** The program conducted the CEV Pad Abort 1 test flight on May 5, 2010. Launch and flight analysis concluded that all flight test objectives were met. | | | |
| 9CS7 (Outcome 4.1) | | | |
| Complete the launch and flight analysis of the Ares 1-X sub-orbital test. | Yellow | The Ares I-X flight test was delayed primarily due to vendor component manufacturing delays, changes to the availability of Space Shuttle Program assets (see Outcome 4.2), and the complexities of loads analyses and certification. | The vendors have delivered all the components for the Ares I-X flight test vehicle to Kennedy Space Center, and the vehicle has been stacked. The project is testing the integrated vehicle elements. In May 2009, the Shuttle Program turned over Pad 39B to the Ares I-X team, following the STS-125 Shuttle mission, and the Ares project began modifying the pad. The flight test occurred in early FY 2010. The project will analyze the flight data and apply it to Ares I computational models, and will continue this task into mid-2010. |
| **FY 2010 Update:** NASA conducted the Ares I-X test flight on October 28, 2009. Subsequent launch and flight analysis concluded that all flight test objectives were met. | | | |
| 9CS9 (Outcome 5.2) | | | |
| Have at least one Partner complete a minimum of one orbital demonstration flight in FY 2009. | Yellow | NASA did not meet the stated APG in FY 2009, but is on track to complete it in FY 2010. During FY 2009, SpaceX notified NASA of delays associated with the maiden launch of its Falcon 9 launch vehicle flight, which impacted their ability to maintain the current launch dates for the NASA COTS demonstration missions. SpaceX has replanned its work and has committed to fly all three COTS demonstration missions in 2010. NASA continues to work closely with SpaceX to provide technical assistance and monitor progress. | The first COTS orbital flight demonstration is now planned for early 2010 and NASA expects that the goals of the program will be met. |
| **FY 2010 Update:** SpaceX successfully launched its Falcon 9 spacecraft on June 4, 2010, and is proceeding toward its first COTS demonstration flight in December 2010. | | | |

| Description | Rating | Why the Measure Was Not Met | Plans for Achieving the Measure in FY 2009 |
|---|---|---|---|
| 9CS11 (Outcome 6.5) | | | |
| Conduct the Lunar Capabilities SRR to define the lunar mission architecture transportation requirements. | Red | NASA did not hold the Lunar Capabilities System Requirements Review (SRR) in FY 2009. NASA established these performance measures while the project was in early formulation. | NASA has scheduled the Lunar SRR for early 2010. NASA replanned the project to reconcile with the availability of funds, and to identify an achievable schedule, with its FY 2010 budget request. However, NASA will re-examine this new project plan after the Review of U.S. Human Spaceflight Plans Committee (also known as the Augustine Committee) releases its final report. |
| **FY 2010 Update:** In the FY 2011 budget process, the President proposed to Congress that the Constellation Program be transitioned to a new set of programs, and NASA adjusted its spending on the program consistent with its budget request and with the Appropriation provided by Congress for FY 2010. NASA has continued its work on Constellation, but reductions in planned work content were made to ensure availability of funds required to complete work already under contract. These reductions have made it difficult for NASA to achieve some of the Constellation Program-related goals and outcomes planned for FY 2010. While NASA determines how to best transition the Constellation Program, consistent with the NASA Authorization Act of 2010 and its FY 2011 Appropriations Act when final, NASA remains poised to leverage Constellation assets to contribute to future exploration beyond low Earth orbit. | | | |
| 9CS12 (Outcome 4.1) | | | |
| Complete the Preliminary Design Review (PDR) for the Constellation Program flight capability (PDR #1). | Yellow | Constellation established the milestone date used for this APG when the program was still in early formulation. Since then, the program refined its schedule in preparation for the FY 2011 budget request. | Constellation's projects contributing to the flight capability have been realigned to the new schedule. The PDR is scheduled for spring 2010. |
| **FY 2010 Update:** In the FY 2011 budget process, the President proposed to Congress that the Constellation Program be transitioned to a new set of programs, and NASA adjusted its spending on the program consistent with its budget request and with the Appropriation provided by Congress for FY 2010. NASA has continued its work on Constellation, but reductions in planned work content were made to ensure availability of funds required to complete work already under contract. These reductions have made it difficult for NASA to achieve some of the Constellation Program-related goals and outcomes planned for FY 2010. While NASA determines how to best transition the Constellation Program, consistent with the NASA Authorization Act of 2010 and its FY 2011 Appropriations Act when final, NASA remains poised to leverage Constellation assets to contribute to future exploration beyond low Earth orbit. | | | |
| **Advanced Capabilities** | | | |
| Outcome 3F.1 | | | |
| By 2008, develop and test candidate countermeasures to ensure the health of humans traveling in space. | Yellow | The Lunar Analog Bedrest Pilot Study (LAPS), a 21-day bed rest study designed to simulate the effects of living on the Moon, was delayed in September 2008 because Hurricane Ike prevented access to the facility. | LAPS resumed operations in April 2009, with the final subject finishing the study in August. Project researchers completed analysis of the data in September. LAPS Phase 2 will commence in November 2009 with completion in May 2010. With completion of this project, and APG 9AC5, Outcome 3F.1 will be back on schedule. |
| **FY 2010 Update:** NASA initiated the Lunar Analog Feasibility Study (LAFS) to assess the feasibility and subject comfort of the Lunar Gravity Simulator. In September 2008, Hurricane Ike delayed facility access to continue the study. LAFS operations resumed in October 2008 and completed tests in August 2009. NASA finished the subject data assessment in November 2009 and held a workshop in December 2009 to review the results and evaluate the proposed Lunar Analog Pilot Study (LAPS) as a bed rest research platform for future lunar analog studies. In February 2010, NASA reviewed the conclusions and recommendations from the workshop and made the decision to discontinue the lunar analog due to difficulties related to validation of this model. | | | |
| 9AC5 (Outcome 3F.1) | | | |
| Validate a ground analog fractional-gravity test methodology to assess whether 1/6th g is protective of physiological systems, including bone loss, and if not, what countermeasures are needed | Yellow | This APG relied on completion of LAPS, which was delayed because Hurricane Ike prevented access to the facility. | LAPS resumed operations in April 2009, with the final subject finishing the study in August. Project researchers completed analysis of the data in September. LAPS Phase 2 will commence in November 2009 with completion in May 2010. |
| **FY 2010 Update:** NASA initiated the Lunar Analog Feasibility Study (LAFS) to assess the feasibility and subject comfort of the Lunar Gravity Simulator. In September 2008, Hurricane Ike delayed the facility access required to continue the study. LAFS operations resumed in October 2008, and tests were completed in August 2009. NASA finished the subject data assessment in November 2009, and held a workshop in December 2009, to review the results and evaluate the proposed Lunar Analog Pilot Study (LAPS) as a bed rest research platform for future lunar analog studies. In February 2010, NASA reviewed the conclusions and recommendations from the workshop and made the decision to discontinue the lunar analog due to difficulties related to validation of this model. | | | |

| Description | Rating | Why the Measure Was Not Met | Plans for Achieving the Measure in FY 2009 |
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| 9AC7 (Outcome 3F.2) | | | |
| Evaluate three alternative distillation technologies for primary water processing as part of closed loop water recovery systems. | Yellow | NASA did not complete the evaluation of the third alternative distillation technology by the end of September 2009 because of manufacturing difficulties. | The NASA will complete the testing by October 13, 2009. The final report comparing the three technologies will be completed by the first quarter of FY 2010. |
| **FY 2010 Update:** NASA completed testing of the third alternative distillation technology in October 2009. NASA finished test analysis in January 2010, and on April 29, 2010, released an independent review panel report, which compared distillation technologies and provided recommendations. | | | |
| 9AC18 (Efficiency Measure) | | | |
| Complete all development projects within 110% of the cost and schedule baseline. | Yellow | While the LRO, LCROSS and the VCAM projects were within their cost baselines, they did not comply with the 110 percent schedule baseline. For LRO and LCROSS, there were technical problems with the launch vehicle systems which contributed to the launch delays. For VCAM, there were technical problems encountered in the development of the instrument which resulted in the schedule delay. | LRO and LCROSS were launched on June 18, 2009, and the VCAM successfully completed its pre-ship review on August 26, 2009. |
| **FY 2010 Update:** While this efficiency was rated yellow in FY 2009 because three projects did not meet schedule baselines, the corresponding efficiency measure for FY 2010 (10AC19) is rated green. ESMD successfully completed all development projects within 110 percent of cost and schedule baselines. | | | |
| **Science Mission Directorate** | | | |
| **Earth Science** | | | |
| 9ES3 (Outcome 3A.1, 3A.5) | | | |
| Develop missions in support of this Outcome, as demonstrated by completing the Glory mission Launch Readiness Review (LRR). | Red | NASA did not complete Glory's Launch Readiness Review due to the failure of the OCO Taurus XL, in addition to issues with the vendor's production of acceptable boards for the Maxwell Single Board Computers. Unfortunately, the team determined that the 24-layer circuit boards originally chosen for the project could not be reliably manufactured, and they are pursuing an alternate design. As a result of both issues, the project has delayed the Launch Readiness Date by 17 months. | The project has switched to an alternate design for the circuit boards and is now working toward a Launch Readiness Review in November 2010. As mentioned above, the Glory launch date will be subject to the completion of the activities required to approve launch of the Taurus XL. |
| **FY 2010 Update:** The circuit boards were completed successfully with the alternate design. However, NASA has set a new launch date of February 2011 for the Glory mission. The new launch date will allow for: 1) closure of the Taurus XL launch vehicle's Return to Flight (RTF) activities, 2) further risk reduction related to spacecraft subsystems, and 3) resolution of launch range manifest conflicts with other scheduled launches. | | | |
| 9ES5 (Outcome 3A.1) | | | |
| Develop mission in support of this Outcome, as demonstrated by completing the CLARREO advanced concepts study. | Yellow | The date for the CLARREO Mission Concept Review was shifted to be consistent with the mission's FY 2010 through FY 2012 funding profile. | The Mission Concept Review, successful completion of which represents completion of the CLARREO advanced concepts study, is scheduled for mid-FY 2010. |
| **FY 2010 Update:** In response to the President's Climate Initiative, NASA reprioritized its Earth Science missions and allocated new funding profiles. According to this new plan, the CLARREO mission scope and concept is being redefined within a cost cap and with a target launch readiness date of 2018. The study team is in the process of finalizing the concept design, and the Mission Concept Review is currently scheduled for November 2010. | | | |

| Description | Rating | Why the Measure Was Not Met | Plans for Achieving the Measure in FY 2009 |
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| 9ES8 (Outcome 3A.2, 3A.4) | | | |
| Develop missions in support of this Outcome, as demonstrated by completing the Global Precipitation Mission (GPM) Confirmation Review. | Yellow | NASA did not complete the GPM Confirmation Review. NASA delayed the GPM confirmation review as a result of an incompatibility between the independent cost estimate developed by the Standing Review Board and the available budget. The project and the Science Mission Directorate have developed an approach and will present it to the Agency for approval at the Confirmation Review. | The Confirmation Review is scheduled to be completed in December 2009. |
| **FY 2010 Update:** The project completed the Confirmation Review in December 2009, and is currently scheduled for launch in 2013. | | | |
| 9ES11 (Outcome 3A.3, 3A.6) | | | |
| Develop missions in support of this Outcome, as demonstrated by completing the Landsat Data Continuity Mission (LDCM) Critical Design Review (CDR). | Yellow | NASA did not complete the LDCM CDR in FY 2009. At Initial Confirmation Review, the Standing Review Board recommended that LDCM's launch readiness date, which was seen as being too aggressive, be changed. The CDR was rescheduled accordingly. | The LDCM CDR is currently scheduled for mid-FY 2010. |
| **FY 2010 Update:** Earth Science adjusted the LDCM mission schedule in response to the SRB's concerns, and the CDR was completed on May 24, 2010. | | | |
| 9ES12 (Outcome 3A.3, 3A.6) | | | |
| Develop missions in support of this Outcome, as demonstrated by completing the DESDynI advanced concept study. | Yellow | The date for the DESDynI Mission Concept Review was shifted to be consistent with the mission's FY 2010 through FY 2012 funding profile. | The Mission Concept Review, successful completion of which represents completion of the DESDynI advanced concepts study, is scheduled for mid-FY 2010. |
| **FY 2010 Update:** In response to the President's Climate Initiative, NASA reprioritized its Earth Science missions and allocated new funding profiles. According to this new plan, the DESDynI mission scope and concept is being redefined within a cost cap and with a target launch readiness date of October 2017. The study team is in the process of finalizing the concept design, and the Mission Concept Review is currently scheduled for early 2011. | | | |
| 9ES16 (Outcome 3A.5) | | | |
| Develop mission in support of this Outcome, as demonstrated by completing the ICESat II advanced concepts study. | Yellow | NASA did not complete the ICESat-2 Mission Concept Review, which represents successful completion of the advanced concepts study. | The February 2009 Mission Concept Review demonstrated inadequate reconciliation of science requirements and mission cost. During the following eight months, the mission implementation approach was refined to meet science objectives within mission cost. The Delta-Mission Concept Review was completed successfully on November 3, 2009. |
| **FY 2010 Update:** The mission implementation approach was refined to meet science objectives within mission cost, and the Delta-Mission Concept Review was completed successfully on November 3, 2009. | | | |

| Description | Rating | Why the Measure Was Not Met | Plans for Achieving the Measure in FY 2009 |
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| 9ES21 (Efficiency Measure) | | | |
| Complete all development projects within 110% of the cost and schedule baseline. | Red | NASA did not complete the Glory mission and the Orbiting Carbon Observatory (OCO) within 10 percent of their cost and schedule baselines. The Glory mission has experienced significant cost and schedule growth due to the failure of the OCO Taurus XL launch vehicle and issues in the vendor's production of acceptable boards for the Maxwell Single Board Computers (SBC). Glory's current projected lifecycle cost is 68 percent higher than the baseline established at the Confirmation Review. The project is currently working toward a November 2010 launch readiness date, a 64 percent increase in schedule. The OCO mission, which was lost in February 2009 due to a launch vehicle failure, slightly exceeded the thresholds, experiencing a 12 percent schedule delay and a 14 percent cost increase. | The Glory mission is currently scheduled for launch in November 2010. |
| **FY 2010 Update:** NASA has set a new launch date of February 2011 for the Glory mission. The new launch date will allow for: 1) closure of the Taurus XL launch vehicle's Return to Flight (RTF) activities, 2) further risk reduction related to spacecraft subsystems, and 3) resolution of launch range manifest conflicts with other scheduled launches. The February 2011 launch date represents a 72 percent increase from the baseline schedule, with the lifecycle cost exceeding the baseline by 68 percent. | | | |
| 9ES24 (Efficiency Measure) | | | |
| Reduce time within which eighty percent of NRA research grants are awarded, from proposal due date to selection, by five percent per year, with a goal of 130 days. | Red | The time-span in which 80 percent of Earth Science selection notifications were made increased during FY 2009. A small number of programs with long notification times, about 35 percent of proposers affected resulted in the lack of improvement in Earth Science notifications. The bulk of notifications are being made more quickly; the median notification time has shown average sustained improvement of six percent per year since FY 2005. In FY 2009, staff turnover, and the need to clear the books of overdue selection notifications from FY 2008, also impacted Earth Science. | Changes being made to reduce delayed selection notifications include scheduling proposal due dates to spread out the work for the understaffed research program managers and providing tentative notifications to proposers when budget uncertainty (e.g., lack of appropriations, lack of operating plan) delays final decision authority. |
| **FY 2010 Update:** The time within which 80 percent of Earth Science selection notifications were made decreased significantly from FY 2009 to FY 2010, from 260 days to 231 days. Better distribution of proposal due dates contributed to this improvement. | | | |
| **Heliophysics** | | | |
| 9HE10 (Efficiency Measure) | | | |
| Complete all development projects within 110% of the cost and schedule baseline. | Yellow | NASA did not complete the Solar Dynamics Observatory (SDO) within 110 percent of cost and schedule baselines. SDO initially slipped from its 2008 firm slot in the launch manifest due to late delivery of avionics boxes and instruments, and problems with electronics parts and the high-speed data bus. SDO has since experienced difficulty obtaining a new slot in the launch manifest, as no firm slots were available until 2010 due to multiple Atlas V launch vehicle issues and associated launch queue delays. | SDO is currently scheduled to launch in February 2010. This exceeds the original schedule by 48 percent, but the mission is still expected to be completed within 10 percent of the original cost baseline. |
| **FY 2010 Update:** NASA launched the Solar Dynamics Observatory in February 2010. This exceeded the original schedule by 48 percent, but the mission's budget remains within 7 percent of the original cost baseline. | | | |

| Description | Rating | Why the Measure Was Not Met | Plans for Achieving the Measure in FY 2009 |
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| **Astrophysics** | | | |
| 9AS5 (Outcome 3D.2, 3D.3) | | | |
| Develop missions in support of this Outcome, as demonstrated by beginning Stratospheric Observatory for Infrared Astronomy (SOFIA) open-door testing. | Yellow | The vendor was late delivering the telescope cavity door controller, causing the delay in testing. The telescope cavity door controller opens and closes a 25-foot-long door on a highly modified 747 aircraft and is, therefore, a flight safety critical system. NASA uncovered technical and quality issues with the controller work at the vendor's facility, requiring NASA project management to station representatives at the facility to oversee the final work leading to the late delivery. This led to a delay in the integration and testing of the controller on the aircraft, and consequently the delay in the open-door flight testing. | The open-door flight testing is scheduled to begin in FY 2010. |
| **FY 2010 Update:** The plan was successful. NASA stationed representatives at the vendor's facility to oversee the final work leading to delivery of the telescope cavity door controller. The first open-door flight test was completed in December 2009. | | | |
| 9AS12 (Efficiency Measure) | | | |
| Complete all development projects within 110% of the cost and schedule baseline. | Yellow | NASA did not complete the Kepler mission within 10 percent of its cost and schedule baselines. The Kepler prime contractor and many of its sub-contractors were not able to execute planned activities within the cost and schedule they had proposed. One of the major challenges was the focal plane array integration. The focal plane on Kepler, with 42 large CCDs, is the largest ever flown in space and has stringent requirements on science performance. Although management changes were made and other actions taken to address issues, the schedule for the focal plane array took longer, and hence cost more, than originally planned. Launch manifest conflicts also contributed to the 24 percent schedule delay and 18 percent cost increase. | NASA launched the Kepler mission on March 6, 2009. |
| **FY 2010 Update:** This action is closed due to the successful launch of the Kepler mission on March 6, 2009. | | | |
| **Planetary Science** | | | |
| 9PS4 (Outcome 3C.1, 3C.2, 3C.3, 3C.4) | | | |
| Develop missions in support of this Outcome, as demonstrated by completing the Mars Science Laboratory (MSL) Launch Readiness Review (LRR). | Red | MSL did not complete the Launch Readiness Review. Development problems with electronic and mechanical devices resulted in slipping MSL's launch to the next Mars launch window in October through December 2011. | NASA re-baselined MSL for launch in the October through December 2011 timeframe. The Launch Readiness Review has been rescheduled to support the new launch period in the first quarter of FY 2012. |
| **FY 2010 Update:** The Launch Readiness Review remains scheduled for the first quarter of FY 2012. | | | |

| Description | Rating | Why the Measure Was Not Met | Plans for Achieving the Measure in FY 2009 |
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| 9PS11 (Efficiency Measure) | | | |
| Complete all development projects within 110% of the cost and schedule baseline. | Red | NASA did not complete the Mars Science Laboratory (MSL) within 10 percent of its cost and schedule baselines. Development problems with critical electronic and mechanical devices resulted in delaying MSL's launch to the next Mars launch window in October-December 2011. This represents a 70 percent schedule increase, with an associated cost increase of approximately 46 percent. | MSL is currently scheduled to launch in November 2011. |
| **FY 2010 Update:** MSL is currently scheduled to launch in the first quarter of FY 2012, with the launch window opening in November 2011. This represents a 70 percent schedule increase, with an associated cost increase of approximately 46 percent. | | | |
| **Space Operations Mission Directorate** | | | |
| **Space Shuttle** | | | |
| 9SSP3 (Outcome 1.2) | | | |
| A 13 percent reduction in Space Shuttle annual value of Shuttle production contracts for Orbiter, External Tank, Solid Rocket Boosters, Reusable Solid Rocket Motor, Space Shuttle Main Engine and Launch & Landing, while maintaining safe flight. | Yellow | NASA maintained production capability to comply with the 2008 NASA Authorization Act, which directed NASA to not take any actions before April 30, 2009 that would preclude extending Shuttle flights beyond FY 2010. The current estimates also include additional production work due to STS-134, which was added to the manifest to launch and install the Alpha Magnetic Spectrometer. | Production of External Tank and Space Shuttle Main Engines is near completion, or completed. NASA will reduce other production contracts, when associated capabilities are no longer needed for safe completion of the Shuttle manifest. |
| **FY 2010 Update:** NASA shipped the final Space Shuttle Solid Rocket Motor segments (RSRM 114) to Kennedy Space Center (KSC) in February 2010 and the final Space Shuttle External Tank (ET-138) to KSC in July 2010. The Agency delivered the last External Tank available for flight (ET-122) to KSC in September 2010. The last Space Shuttle Main Engine scheduled for flight (SSME 2061) was delivered to KSC in August 2009. Production contract values declined by 3 percent between FY 2008 and FY 2009, from $1.96 billion to $1.90 billion, and are projected to decline by an additional 22 percent to $1.48 billion in FY 2010. Residual contract value will be maintained through the end of the program to support sustaining engineering activities associated with mission execution. | | | |
| **International Space Station** | | | |
| 9ISS4 (Outcome 2.1) | | | |
| Provide increased ISS capability by assembling the remaining two Japanese Exploration Agency (JAXA) elements, the Exposed Facility (EF) and the Experiment Logistics Module-Exposed Section (ELM-ES), and the NASA EXPRESS Logistics Carriers (ELC) as baselined in FY 2009. | Yellow | NASA launched and assembled the elements of the Exposed Facility and the Experiment Logistics Module, except for the ELCs. | NASA plans to launch and install the ELCs in early FY 2010. |
| **FY 2010 Update:** This performance improvement plan was not met due to delays in the Space Shuttle launch schedule caused by the late delivery of the Alpha Magnetic Spectrometer (AMS) payload. NASA launched two of four planned hardware deliveries to the ISS in FY 2010. The last two pieces of hardware, along with the Permanent Multipurpose Module (PMM) and AMS, will be launched in FY 2011. | | | |
| **Space and Flight Support** | | | |
| 9SFS3 (Outcome 3F.4) | | | |
| Capture 100% of medical and environmental data required by Medical Operations in queriable form. | Yellow | Capturing the relevant data is an information technology-based task. The resources necessary to accomplish this task were diverted to work on the Homeland Security Presidential Directive 12 requirement for common identification standards across the Federal government. The action only impacts the timeframe for completion. | CHSP plans to continue with the original set of activities, but with a five-month slip in schedule. The completion date will be the second quarter of FY 2010 rather than the fourth quarter of FY 2009. |
| **FY 2010 Update:** Crew Health and Safety met its targeted completion by the second quarter of FY 2010 and captured all relevant data as originally planned. | | | |

| Description | Rating | Why the Measure Was Not Met | Plans for Achieving the Measure in FY 2009 |
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| 9SFS4 (Outcome 4.1) | | | |
| Coordinate rocket propulsion test activities to support Constellation rocket propulsion testing milestones by providing an agency level Rocket Propulsion Test Plan. | Yellow | Changes to the Constellation Program's schedule and the resulting changes in the respective test programs delayed development of the Rocket Propulsion Test Plan. | At this time enough information exists to create an appropriate plan. Areas where there are still decisions to be made or revisited will be incorporated in the initial plan or revised in yearly updates. A team lead by a NASA Senior Executive will have a final plan by August 2010, and management for the Space Operations Mission Directorate will review and approve the plan by the end of FY 2010. |
| **FY 2010 Update:** The Rocket Propulsion Test (RPT) Master Plan is on track for delivery by December 2010, following a carefully constructed 11 month milestone schedule including plan development, a Gap Analysis, and a 90-Day study to assess Chemical Propulsion Information Analysis Center (CPIAC) Database Enhancements, and a U.S. Test Stand Capabilities Analysis. Each of these milestones were completed in August 2010. Currently, report formulation is in work with Center reviews scheduled for the November 2010 timeframe. The RPT Program keeps Space Operation Mission Directorate (SOMD) apprised of the plan's progress through the SOMD Directorate Program Management Council (DPMC). | | | |
| 9SFS7 (Outcome 6.4) | | | |
| Re-compete the Space Network, Near Earth Network and NISN operations and maintenance contracts to provide uninterrupted support of those networks. | Yellow | NASA did select a contractor for the operations and maintenance contract. However, two protests were filed against NASA's decision, which delayed the contract award. NASA extended the current contract to avoid an interruption in support. | The protests are currently under review. SCaN has plans in place to implement this goal once the protests are adjudicated and an award can be made. Network Services continue uninterrupted, but the long-term impact is under assessment due to personnel attrition created by contract uncertainty. |
| **FY 2010 Update:** The protest has not yet been resolved and an award has not been made; however, Network Services continue uninterrupted. NASA management is assessing the potential long-term impact of this delay, including the effect on personnel attrition created by contract uncertainty. | | | |

| Description | Rating | Why the Measure Was Not Met | Plans for Achieving the Measure in FY 2009 |
|---|---|---|---|
| **Education** | | | |
| **Education** | | | |
| 9ED3 (Outcome ED-1) | | | |
| Engage 8,500 underrepresented and underserved students in NASA higher education programs. | Red | In FY 2008, 6,776 higher education students self-reported being part of an underserved and underrepresented audience (based on race or ethnicity). This represents 28 percent of the number of higher education students served by NASA in FY 2008. Of all higher education students, 41 percent self-reported being women. (Note: data reported is from FY 2008 due to the grant reporting cycle.) The reduction in direct student support reflects an increased Congressional emphasis on research, achieved through institutional (not individual student) awards. The overall reduction in direct support to higher education students affects the total number of higher education underserved and underrepresented students reached by the Office of Education. In FY 2007, the total number of higher education students reached was 34,493; in FY 2008, it dropped to 24,362. Higher education projects have shifted operations to address this new direction, but there is significant lag time before results are available (e.g., new course development time, time to execute activities, grant reporting lag time). Additionally, budgets for higher education projects are effectively flat-lined, but per participant costs for grants are increasing. To offer competitive awards to individuals, NASA grantees (e.g., Space Grant) must increase award sizes that meet cost increases in tuition, travel, and other expenses. In a flat budget environment, an increase in award size means that fewer direct support awards can be made. | All higher education projects are actively working to increase engagement of underrepresented and underserved students. For example, Space Grant program management is successfully encouraging state consortia to increase efforts to engage underrepresented students and to better include more minority-serving institutions in their organizations. In FY 2007, 15 percent of all students reached by Space Grant self-reported being of an underrepresented race or ethnicity. This percentage rose to 21 percent in FY 2008. Future efforts include work with community colleges, an environment with large numbers of underserved audiences. |
| **FY 2010 Update:** All higher education projects are actively working to increase engagement of underrepresented and underserved students. Future efforts include work with community colleges, an environment with large numbers of underserved audiences. For example, Space Grant program management is successfully encouraging state consortia to increase efforts to engage underrepresented students and to better include minority-serving institutions in their networks. The strategy has been successful, as participation of racially and ethnically underserved and underrepresented students in Space Grant has increased from 15 percent in FY 2007, to 21 percent in FY 2008, and 29 percent in FY 2009. | | | |

| Description | Rating | Why the Measure Was Not Met | Plans for Achieving the Measure in FY 2009 |
|---|---|---|---|
| 9ED14 (Efficiency Measure) | | | |
| Reduce the cost per K-12 program participant over FY 2007 amounts by 1%. | Red | Research in science, technology, engineering, and mathematics (STEM) education shows that projects and activities that provide hands-on experiences, intensive internships, and sustained educator professional development relationships are more effective in positively affecting STEM teaching and learning. NASA's Office of Education (OE) has strategically adjusted its elementary and secondary portfolio to include greater investments in these types of experiences, which are more costly, but more effective that short-term, broad-based activities like one-time workshops, auditorium-style presentations and school visits, etc. Elementary and secondary education programming is changing direction within a flat-line (or decreasing core program budget) and this goal is no longer feasible. | OE is pursuing increased investment in activities with higher per participant costs. A balanced OE education portfolio still includes projects and activities with lower costs per participant and reaches large numbers of students and educators. Averaging these different types of investments in one efficiency measure is not practical. OE plans to work with their OMB analyst to revise the performance measure to more accurately reflect new OE strategies and Administration emphasis on high-impact (high cost per participant) investments. |
| **FY 2010 Update:** The Office of Education has a number of elementary and secondary projects that respond to education research showing that positive impacts in STEM teaching and learning are achieved through high-touch/high cost per participant types of investments. This strategy to increase the desired impact of education investments is contrary to the APG for reducing costs. The Office of Education plans to work with their OMB analyst to develop a more appropriate efficiency goal. | | | |
| **Cross-Agency Support Systems** | | | |
| **Advanced Business Systems (Agency IT Services)** | | | |
| 9IEM5 (Outcome IEM-2) | | | |
| Achieve cost savings, expected to increase annually with a 2009 goal of $19.3M, resulting from the integration of financial and asset management systems, a reduction in the number of redundant property, plant and equipment (PP&E) systems and process improvements that enable NASA to better manage PP&E assets. | Red | NASA implemented the PP&E System in May 2008 resulting in a cost savings during FY 2009 of $14.7 million, which is 76 percent of the goal as currently stated. However, further evaluation early in the Implementation Phase while providing a business case update resulted in the cost savings for the project being reduced. The initial benefit cost savings for reutilization of assets and loss reduction was overstated substantially based on the recent year's data. However, the NASA FY 2009 Performance Plan measure had already been submitted prior to this revision in cost savings. | The APG was unrealistic and will not be achieved as currently stated. |
| **FY 2010 Update:** No Performance Improvement Plan is provided, as there is no possible follow up action needed. The metric was not achieved, because the metric was not realistic and far overstated, based upon final FY 2009 cost benefit analysis. | | | |

| Description | Rating | Why the Measure Was Not Met | Plans for Achieving the Measure in FY 2009 |
|---|---|---|---|
| 9IEM9 (Efficiency Measure) | | | |
| Reduce the number of financial processing steps/time to perform year end closing from the 2005 baseline of 120 steps to the 2008 goal of 20 steps (an 83% reduction). | Red | The focus of the measure collection, as written, is on the number of processing steps required to support yearend close. The FY 2008 year-end closing required 98 steps and a system run time of 59 hours (three days). However, a more accurate measure of efficiency improvements achieved is the amount of time that the system is not available to the end users. The system unavailability was reduced from 60-system hours/four and one-half days. The reduction in time relates to system unavailability for processing and that is what is important to the end users. Although the number of steps was not reduced as planned with the upgrade to SAP version ECC 6.0, there was significant reduction in the amount of time that SAP was unavailable to end users during the close process. The upgrade to ECC 6.0 reduced runtime of closing programs from 60 hours to 51 hours, and allowed analyst to perform concurrent years processing, entering FY 2008 data within days of closing the last period in FY 2007. | The reduction in number steps is not an accurate measure of efficiency achieved. The more important measure is the amount of system downtime reduced, which impacts the end users. Therefore, a more appropriate APG has been incorporated into the FY 2010 Performance Plan, to accurately measure the improvements. APG 10IT12 states, "In 2010, reduce the amount of system execution time during the year-end close process by six hours." Based on improved performance of additional hardware, preliminary FY 2009 system executive hours are on target for the six hour reduction noted in FY 2010 Performance Plan measure. |
| **FY 2010 Update:** The Process Improvement Plan was translated into a new APG (AGP 10IT12), which stated: "In 2010, reduce the amount of systems execution time during the year-end close process by six hours." This measure is included in this 2010 report, wherein the Agency reduced the year-end process time from 59.0 hours/three days to the current 50.5 hours of lost process time while the year-end process was being closed-out. | | | |

Credit: NASA/ J. Pfaller

At Launch Complex 41 on Cape Canaveral Air Force Station, NASA's Solar Dynamics Observatory, or SDO, enclosed in the Atlas V payload fairing, is lifted from its transporter up the side of the Vertical Integration Facility. The fairing will be placed on top of the rest of the Atlas V rocket, the brown column visible inside the facility. SDO launched a couple of weeks later, on February 11, 2010.

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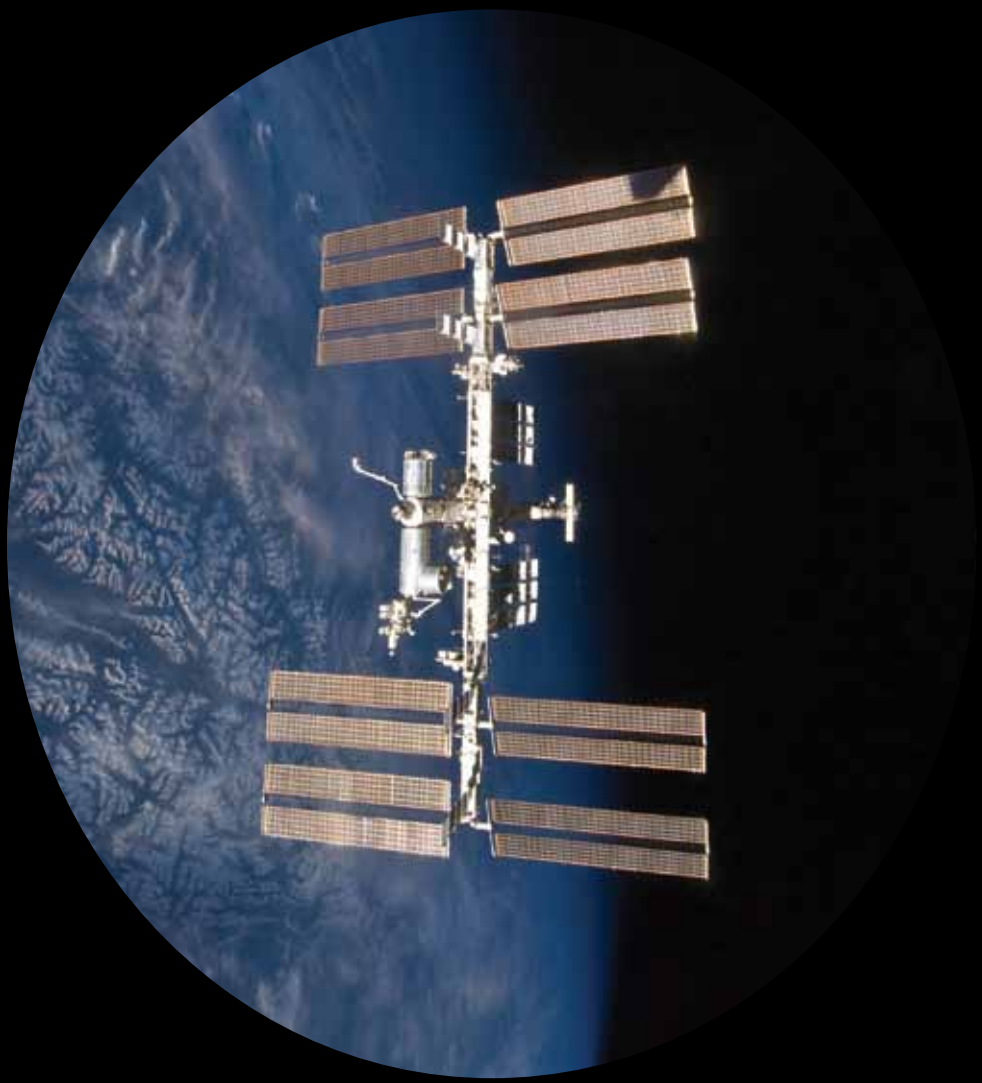
Photo back cover: Backdropped by Earth's horizon and the blackness of space, the International Space Station is featured in this image photographed by an STS-131 crewmember after Space Shuttle *Discovery* began to undock and separate from the Station. (Credit: NASA)



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